A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area

ME 3.4

June 1977

L.E.R.

Sponsored jointly by

Alberta ENVIRONMENT

Environment Canada Environnement Canada

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91-03418/

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975.

A list of the research reports published to date is included at the back of this report.

Enquiries pertaining to the Alberta-Canada Agreement or other reports in the series should be directed to:

Alberta Oil Sands Environmental Research Program
15th Floor, Oxbridge Place
9820 - 106 Street, Edmonton, Alberta T5K 2J6
Telephone (403) 427-3943

A Climatology of Low-Level Air Trajectories in the Alberta Oil Sands Area

Project ME 3.4

AOSERP Report 15

LETTER OF TRANSMITTAL

The Hon. D. J. Russell
Minister of the Environment
222 Legislative Building
Edmonton, Alberta.

and

The Hon. R. LeBlanc
Minister of Fisheries and the Environment
Parliament Buildings
Ottawa, Ontario.

Sirs:

Enclosed herein is the report on, "A Climatology of Low-Level Air Trajectories in the Alberta Oil Sands Area".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Meteorology and Air Quality Sector, under the Alberta-Canada Agreement of 28 February 1975.

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

for J. S. Tener, Ph.D.
Member, Steering Committee, AOSERP
Assistant Deputy Minister
Environmental Management Service
Fisheries and the Environment Canada.

A Climatology of Low-Level Air Trajectories in the Alberta Oil Sands Area

Descriptive Summary

Abstract

The objective of this project was to develop a climatology of air parcel movements (trajectories) over 72-hour periods for parcels moving in to and out from the AOSERP study area. The trajectories were required at 1000 mb (surface), 925 mb (750 m above surface) and 850 mb (1500 m above surface), and for conditions of nil, light, moderate and heavy precipitation. The basic data used to construct the 72-hour trajectories were the four times daily surface and twice daily 850 mb AES weather maps on microfilm for 1968 and 1973-74-75. Seasonal patterns of frequency distribution are consistent from the west for air parcels moving in to the study area and to the east for air parcels moving out from the study area, except that in Spring at the surface the southeasterly direction is more frequent for air moving into the study area and the northwesterly direction more frequent for air moving out from the study area.

Background and Perspective

This study was designed to provide a climatology of air trajectories in the AOSERP study area. Such information will contribute to the best design for air and precipitation sampling networks and in the selection of the best locations for sampling soils and lakes to monitor long term trends in pollutant deposition. In addition, it may serve as the basis for a statistical regional dispersion and deposition model.

Four years of microfilmed Canadian Meteorological Centre weather maps (surface and 850 mb) were obtained and forward and backward 72 hour trajectories were constructed for each day into and out of the study area at three levels (surface, 925 mb, 850 mb).

These trajectories were correlated with precipitation occurrences (nil, light, moderate, heavy) at Ft. McMurray and trajectory frequency diagrams were produced on an annual and seasonal basis for each level and precipitation class as data permitted.

The flow patterns into the AOSERP study area showed vertical consistency and were predominantly from the SW to NW and mainly from the NE to SE leaving the area. There was a secondary component from the SE into the area in the spring at the surface for nil and light precipitation and toward the NW leaving the AOSERP study area. The greatest trajectory frequencies occurred with the light precipitation condition.

Assessment

The Meteorology and Air Quality Technical Research Committee of AOSERP has reviewed and accepted the report which was prepared by Acres Consulting Services Limited of Niagara Falls, Ontario. The content of the report does not necessarily reflect the views of Alberta Environment, Fisheries and Environment Canada or the Oil Sands Environmental Study Group.

The author successfully developed a climatological trajectory analysis methodology by manually examining microfilmed weather maps and precipitation data. The large number of trajectories were grouped into precipitation classes and time periods and displayed in a very effective manner on a trajectory frequency diagram centered in the oil sands area. The work was done in an efficient and effective manner with full communication, discussion and cooperation as required.

The Meteorology and Air Quality Technical Research Committee under the Chairmanship of Mr. F. E. Burbidge, Atmospheric Environment Service, Edmonton, has recommended the report for publication. The Alberta Oil Sands Environmental Research Program accepts the report "A Climatology of Low-Level Air Trajectories in the Alberta Oil Sands Area" as an important

and valid research document, in the series of AOSERP reports, and thanks the researcher for his contribution.

S. B. Smith
Director
Alberta Oil Sands Environmental
Research Program.

A CLIMATOLOGY OF LOW-LEVEL AIR TRAJECTORIES IN THE ALBERTA OIL SANDS AREA

by

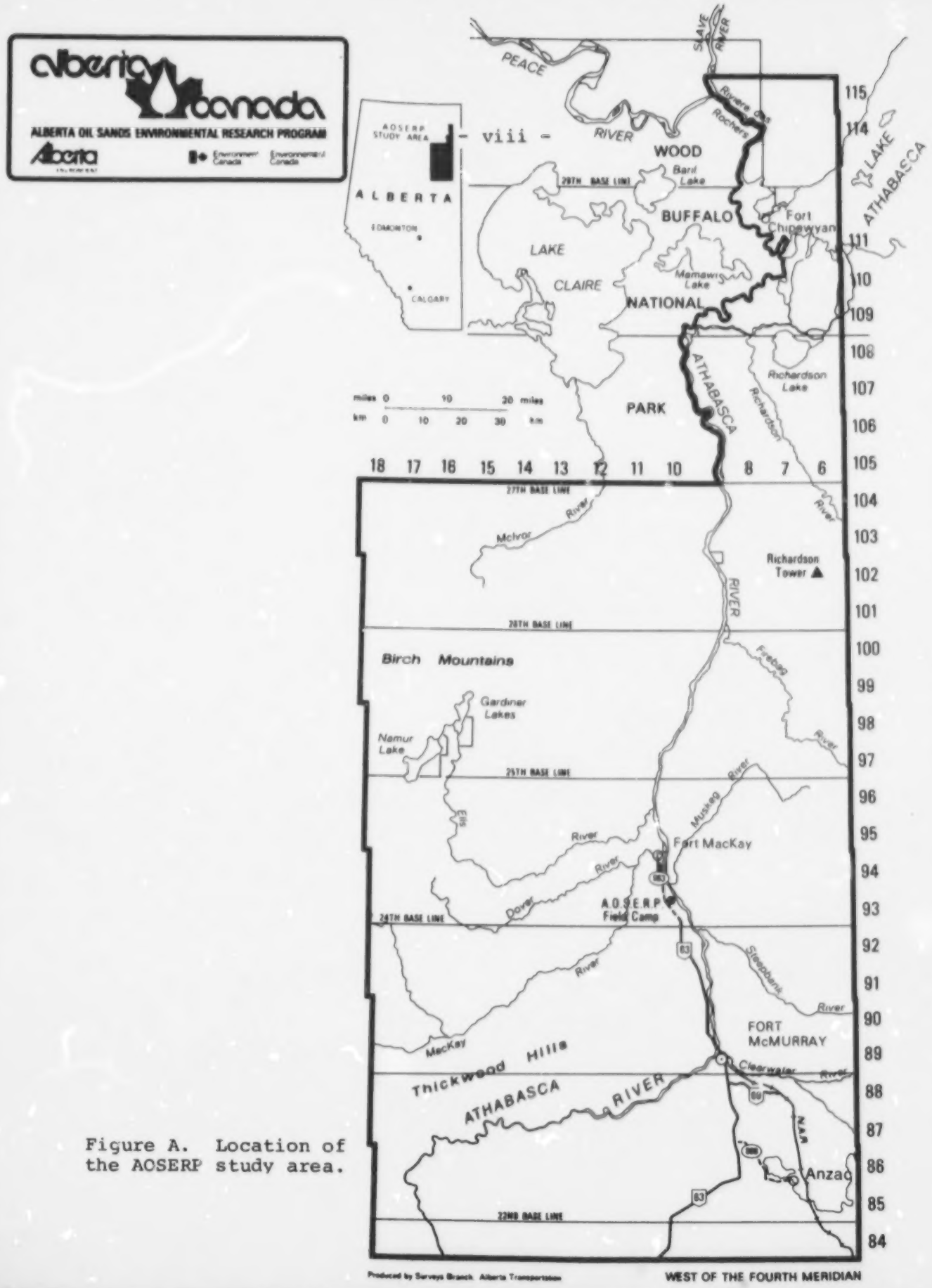
P. J. DENISON
ACRES CONSULTING SERVICES

for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
METEOROLOGY AND AIR QUALITY SECTOR

PROJECT ME 3.4

January 1977



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1 - INTRODUCTION

By contract dated April 23, 1976 (Supply and Services Canada 04SZ. KM 601-5-1157) Acres Consulting Services was authorized to make the study, "A Climatology of Low-Level Air Trajectories in the Alberta Oil Sands Area". The study is part of the Alberta Oil Sands Environmental Research Program (AOSERP) sponsored jointly by Alberta Environment and Fisheries and Environment Canada. The Scientific Authority responsible for all matters concerning the scientific and technological content of the work was Mr. M. P. Olson, Atmospheric Environment Service (AES). The principal investigator on the project was Mr. P. J. Denison, Acres Consulting Services (ACS). One initiation and three progress meetings were held during the course of studies.

2 - OBJECTIVES

In the AOSERP First Annual Report, 1975, the objective of this subproject was defined as follows:

"to develop a trajectory analysis capability and provide a statistical compilation of horizontal trajectories for the oil sands area, computed on the basis of synoptic wind observations and/or geostrophically computed winds".

The annual report further states that "Information generated by this study will contribute to the best design for air and precipitation sampling networks and in the selection of the best locations for sampling soils and lakes to monitor long-term trends in emission deposition. In addition, it may serve as the basis for a statistical regional dispersion and deposition model."

3 - SCOPE OF WORK

The work requirements given in the Request for Proposal on this project included the following:

(a) Review existing trajectory analysis techniques with the objective of developing a suitable procedure for use here;

(b) Use existing meteorological data (upper air soundings, maps etc.) for a climatologically representative period to calculate air parcel trajectories arriving at and leaving the oil sands area (AOSERP study area).

Required also was a description of the period chosen for analysis and a demonstration that it is of sufficient length from which to compile statistics and is representative climatologically.

A statistical description of the computation results was required for the following cases:

- Trajectories arriving at and leaving the oil sands area
- Stratified by seasons (as appropriate from data)
- At the 1,000- (surface), 925- and 850-mb levels*
- Stratified by precipitation conditions (e.g. dry, showery, rain).

---

*1,000, 925 and 850 mb are constant pressure surfaces, the heights of which vary in space and time. Height contours drawn on these surfaces are approximately equivalent to pressure contours (isobars) drawn at the surface, 2,500 feet (750 m) above surface, and 5,000 feet (1,500 m) above surface.

These work requirements were expanded upon and detail was added in the ACS response to the Request for Proposal, as well as in meetings with the Scientific Authority and other AES personnel subsequent to the award of contract.

Budget constraints limited the length of record which could be analyzed. However, previous studies, such as the development of wind-wave climatologies in a number of areas, have suggested that a 4-year period provides sufficient data to reach a climatologically stable result. It was decided that 3 of these years should be the most recent for which complete and readable microfilmed data were available, viz. 1973, 1974 and 1975, and that the fourth year, to serve also as a test year, should be at least 5 years earlier with the same requirement for complete and readable microfilmed data. The year 1968 best met these latter requirements.

The scope of work agreed upon divided into the following tasks:

- Analysis of 72-hour surface and 850-mb trajectories for the 4 years, 1968, 1973-1974-1975, and interpolation for the 925-mb level;

- Grouping of trajectories according to precipitation conditions, nil-light-moderate-heavy;

- Computation of the frequencies of occurrence of air parcels determined by sixteen directional sectors from and circumferences drawn at successive 150-mile radii around the study area;

- Comparison of annual frequencies as determined above for 1968 and 1973-1974-1975 at the surface and 850-mb level to assess representativeness of study period; it was decided that a difference of less than 90 degrees in the dominant trajectory directions would indicate stability in the data sample;

- Analysis of total annual frequencies for the 4 study years;

- Analysis of seasonal frequencies for the 4 study years for conditions of nil and light precipitation and for the surface and 850-mb levels only;

- Spot checks on the reproducibility of 25 trajectory analyses.

Figure 1 is a location map showing the general study area in relation to geographical features and place names.

The actual steps in analysis and documentation of results are detailed in Sections 4 and 5 following.

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AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

LOCATION MAP

NOVEMBER 1976 | FIGURE 1

4 - TRAJECTORY ANALYSES

4.1 - Analytical Procedures

A review of trajectory analysis techniques included the following:

Bolin B. and C. Persson. Regional Dispersion and Deposition of Atmospheric Pollutants with Particular Application to Sulfur Pollution over Wester Europe. *Tellus XXVII (1975), 3. pp 284 - 310.*

Godske C. L., T. Bergeron, J. Bjerknes, R. C. Bundgaard. *Dynamic Meteorology and Weather Forecasting.* American Meteorological Society and Carnegie Institution of Washington, 1957.

Smith F. B., and F. G. Jeffrey. Airborne Transport of Sulphur Dioxide from the U.K. *Atmospheric Environment June/July 1975.*

Wendell, L., Model of Northeastern U.S.A. Sulfur Trajectories. *Symposium on Atmospheric Turbulence and Diffusion, Raleigh, N.C., October 1976.*

Rao, K.S., J. S. Legue and B. A. Egan. Air Trajectory Model for Regional Transport of Atmospheric Sulphates. *Symposium on Atmospheric Turbulence and Diffusion, Raleigh, N.C., October 1976.*

The large number of microfilmed weather maps that required individual viewing and analysis suggested that the trajectories can be constructed manually as described following, and as used in the Acres study for Environment Canada "Atmospheric Loading of the Upper Great Lakes" and the extension of that project in the study now nearing completion, "Atmospheric Loading of the Lower Great Lakes and the Great Lakes Drainage Basin". This same technique has been used by the principal investigator in developing wave climatologies for Quebec Cartier Mining Company at Port Cartier, P.Q., and for the Asbestos Corporation in Deception Bay, P.Q. The technique has been used in air pollution studies involving trajectory analyses, e.g. Smith and Jeffries, and Wendell above.

The data sources for this work item were AES microfilms of the historical weather map series as analyzed by the Central Analysis Office in Montreal for the surface and 850-mb levels in the years 1968, 1973, 1974 and 1975. This form of data storage provided major advantages over the more conventional paper map series for both handling and speed of viewing of the approximately 8,800 analyzed weather maps from which the 72-hour trajectories were constructed.

Four 6-hour trajectories at the surface level and two 12-hour trajectories at the 850-mb level were determined each day, both for air parcels leaving the study area and air parcels arriving at the study area. These were composited over successive 72-hour periods, so that once daily at 0000 GMT 72-hour trajectories were drawn for air moving in to and out from the study area at the two levels. Trajectories of air parcels moving in to the study area were obtained by back-tracking from the end of the analysis period. Trajectories at the 925-mb level were obtained by interpolation between the surface and 850-mb levels.

On the surface level maps, measured winds were normally plotted in the general vicinity of the study area. Where the isobaric or height contour gradients drawn on the weather maps agreed with the plotted winds, allowing for the normal cross isobaric flows and frictional reduction in wind speeds, the plotted winds were accepted in the trajectory analysis. As a consequence, topographical effects on airflows such as by valleys, ridges, changes in land cover type, have been factored into the analysis.

At the 850-mb level, the same general approach was followed as in the surface level case, except that no boundary layer effects were allowed for, so that an 850-mb plotted wind that was judged to be representative of the study area on the basis of the 850-mb height contour pattern was accepted in the trajectory analysis.

In the few cases where no winds were plotted or when the plotted winds did not conform at one or both of the levels to the height contour patterns, the latter were used in the trajectory analysis, allowing for the usual boundary layer effects on surface level wind speeds and directions.

Examples are shown in Figures 2 to 11 selected at random from the approximate total of 8,800 trajectories analyzed.

4.2 - Reproducibility

In order to provide a measure of accuracy of the analysis of individual 72-hour trajectories, a randomly selected sample of 25 cases was reanalyzed two months after and without later reference to the original analyses. The differences in each set of trajectories were measured as differences in orientation expressed as degrees, and as differences in travel distance expressed as miles. The results given in Table 1 show an acceptable level of accuracy with relatively small differences in both trajectory orientation and length. The signs of differences in angle of trajectory orientation are positive when the second analysis gave an orientation that was in a clockwise direction from the first, and vice versa. Distance differences are marked positive when the second trajectory was longer than the first. As can be seen, these differences are random and tend to cancel over time.

TABLE 1

RESULTS OF REANALYSIS OF RANDOMLY SELECTED 72-HOUR TRAJECTORIES

Difference in Trajectory Angle (°)*		Difference in Trajectory Length**	
Surface	850 mb	Surface	850 mb
+10	+ 5	+15	+30
+15	0	+30	+75
- 5	-10	0	-15
0	+ 5	+45	+45
-15	- 5	-15	-60
0	-10	+45	+30
-10	0	+15	+45
+ 5	- 5	-60	-75
+20	0	0	-15
-10	-15	-30	-60
+10	+10	+75	+90
+ 5	+20	+45	+30
0	+ 5	-15	-45
0	-10	-60	0
+ 5	+10	+15	+75
+15	+20	-30	-45
-10	- 5	-15	-60
-20	0	-75	-90
+ 5	+15	0	+30
0	- 5	-30	0
-10	-20	+45	+75
+ 5	0	+30	+60
+15	+15	-90	-30
0	-15	+45	+15
-10	-10	- 0	-45
AM = 0.8 SD = 10	AM = -0.2 SD = 11	AM = -0.6 SD = 42	AM = 7.2 SD = 53

* To the nearest 5°
**To the nearest 15 miles

LEGEND

SURFACE

925 mb

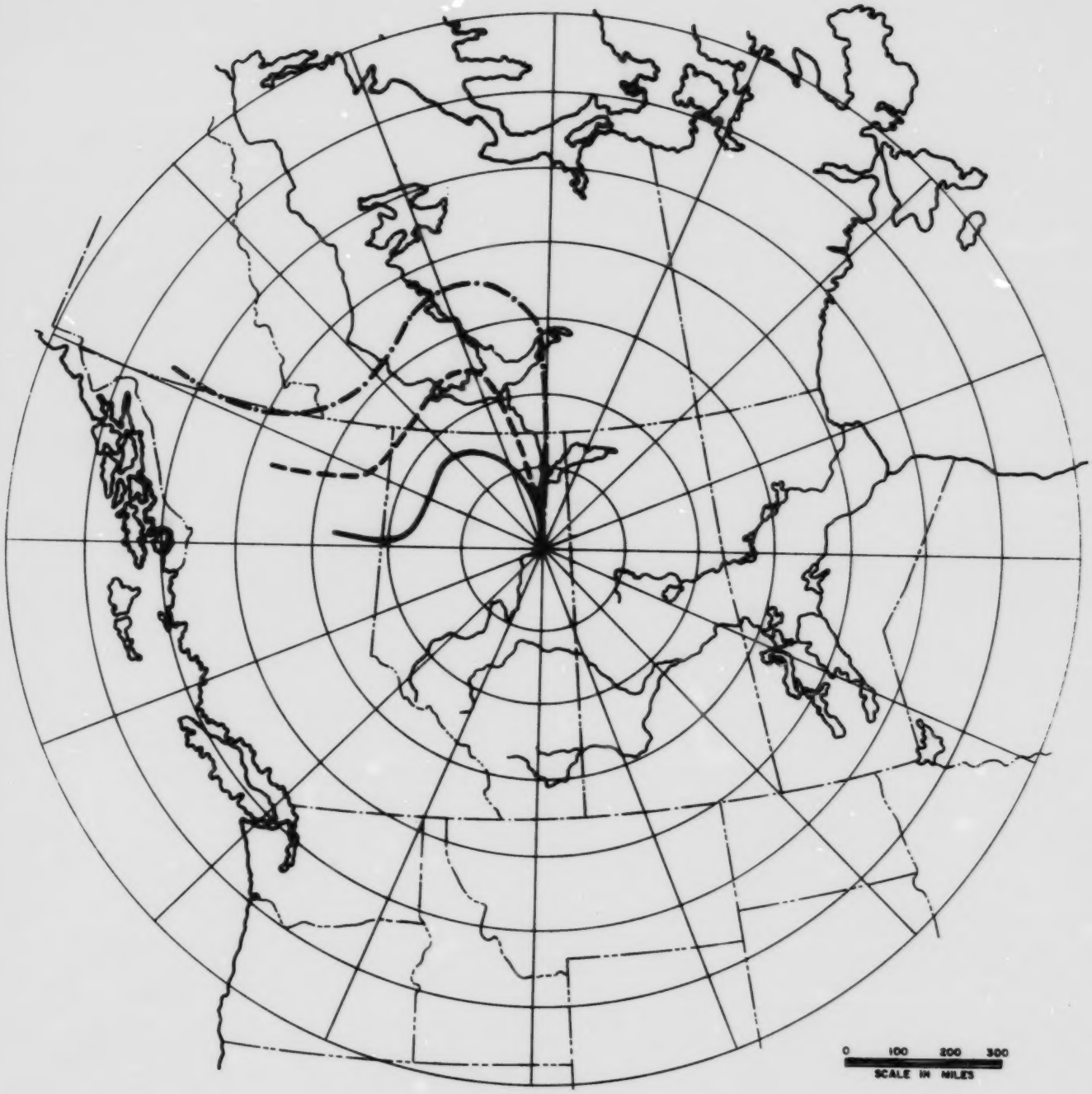
850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - AUGUST 11, 1968
DIRECTION - IN TO STUDY AREA

NOVEMBER 1976 | FIGURE 2



LEGEND

SURFACE

925 mb

850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - FEBRUARY 4, 1968
DIRECTION - OUT FROM STUDY AREA

NOVEMBER 1976 | FIGURE 3

LEGEND

SURFACE

925 mb

850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - FEBRUARY 8, 1973
DIRECTION - OUT FROM STUDY AREA

NOVEMBER 1976 | FIGURE 4

LEGEND

SURFACE

925 mb

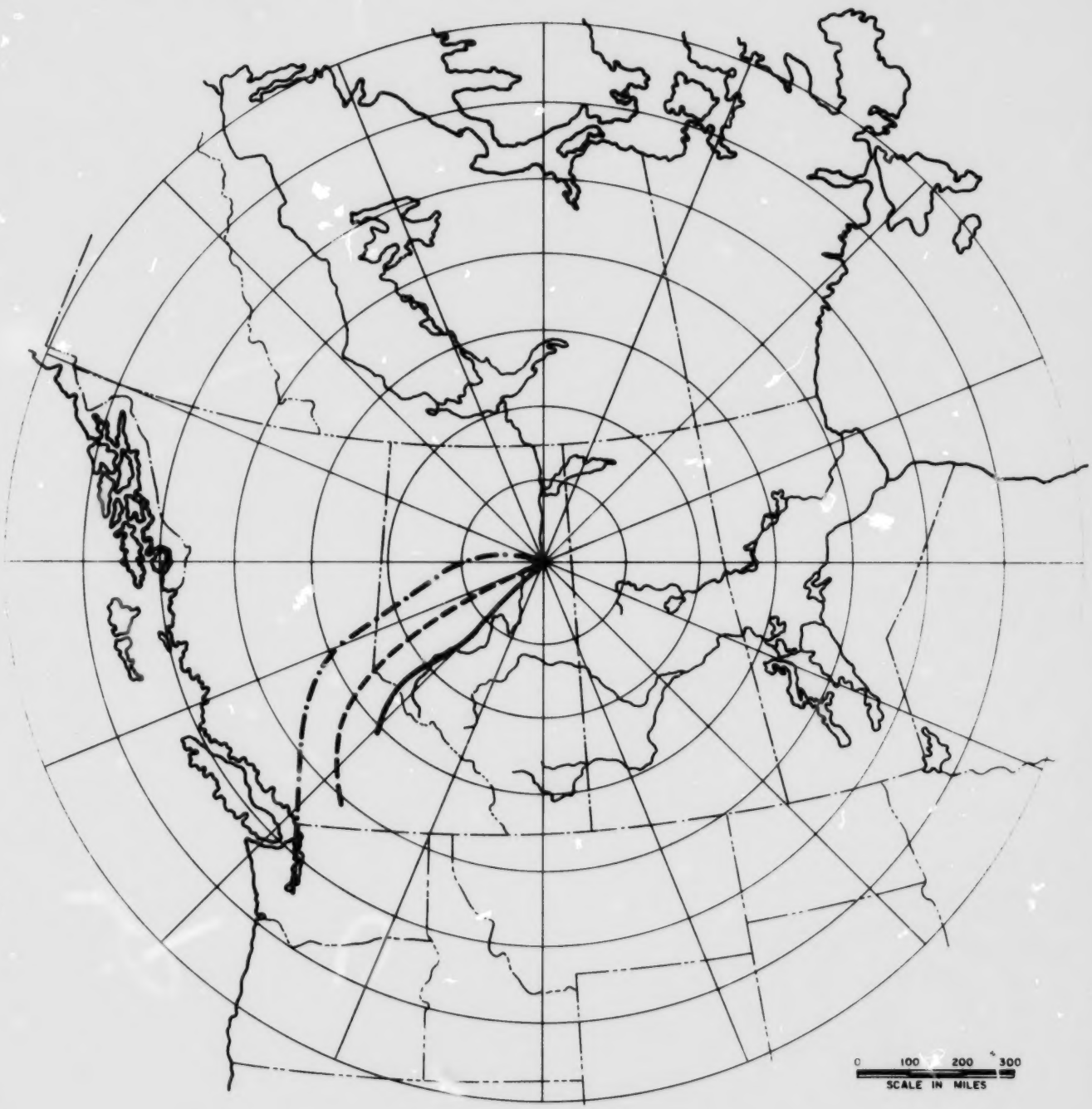
850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - MARCH 11, 1973
DIRECTION - OUT FROM STUDY AREA

NOVEMBER 1976 | FIGURE 5



LEGEND

SURFACE

925 mb

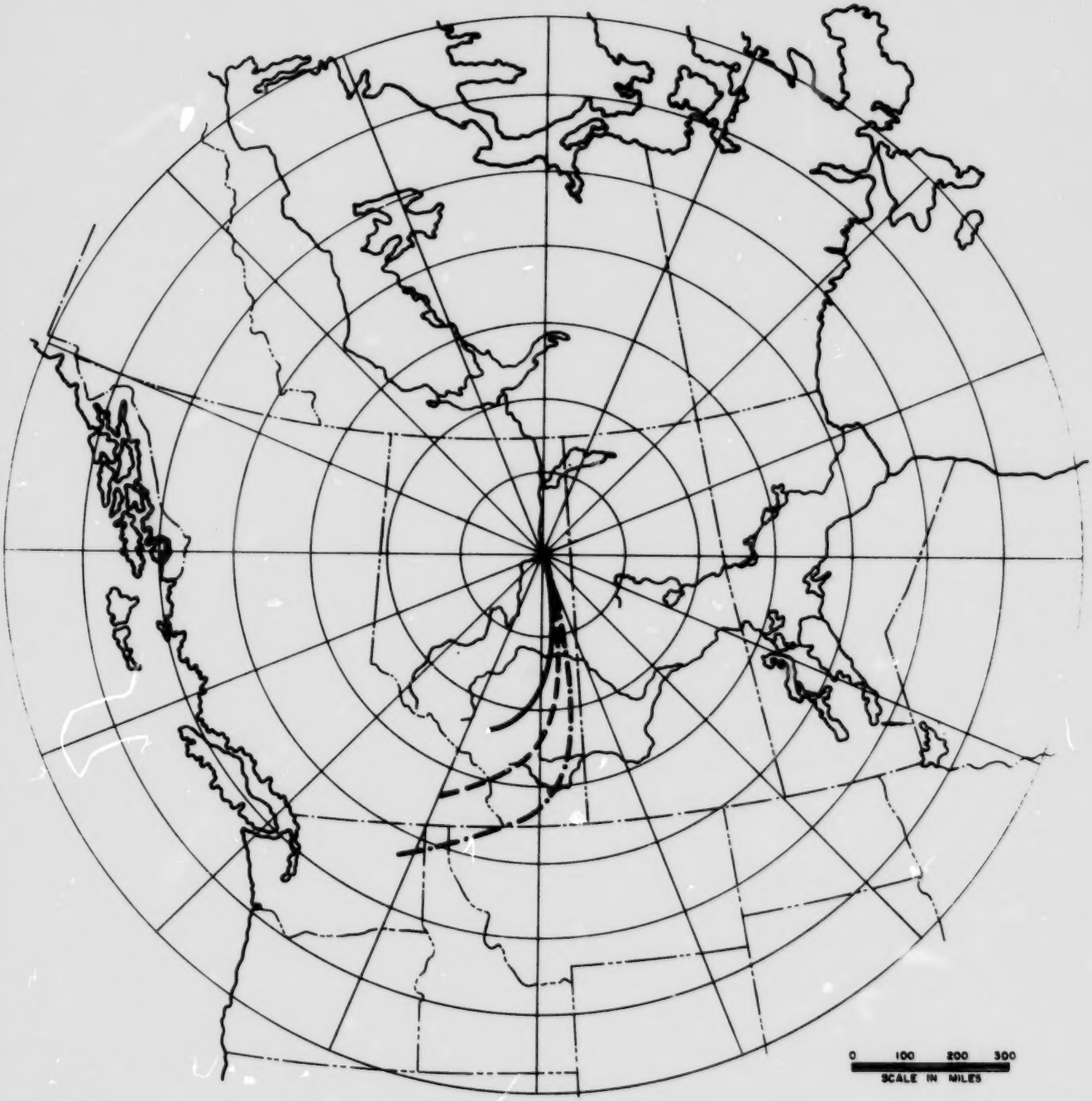
850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - MARCH 31, 1973
DIRECTION - IN TO STUDY AREA

NOVEMBER 1976 | FIGURE 6



LEGEND

SURFACE

925 mb

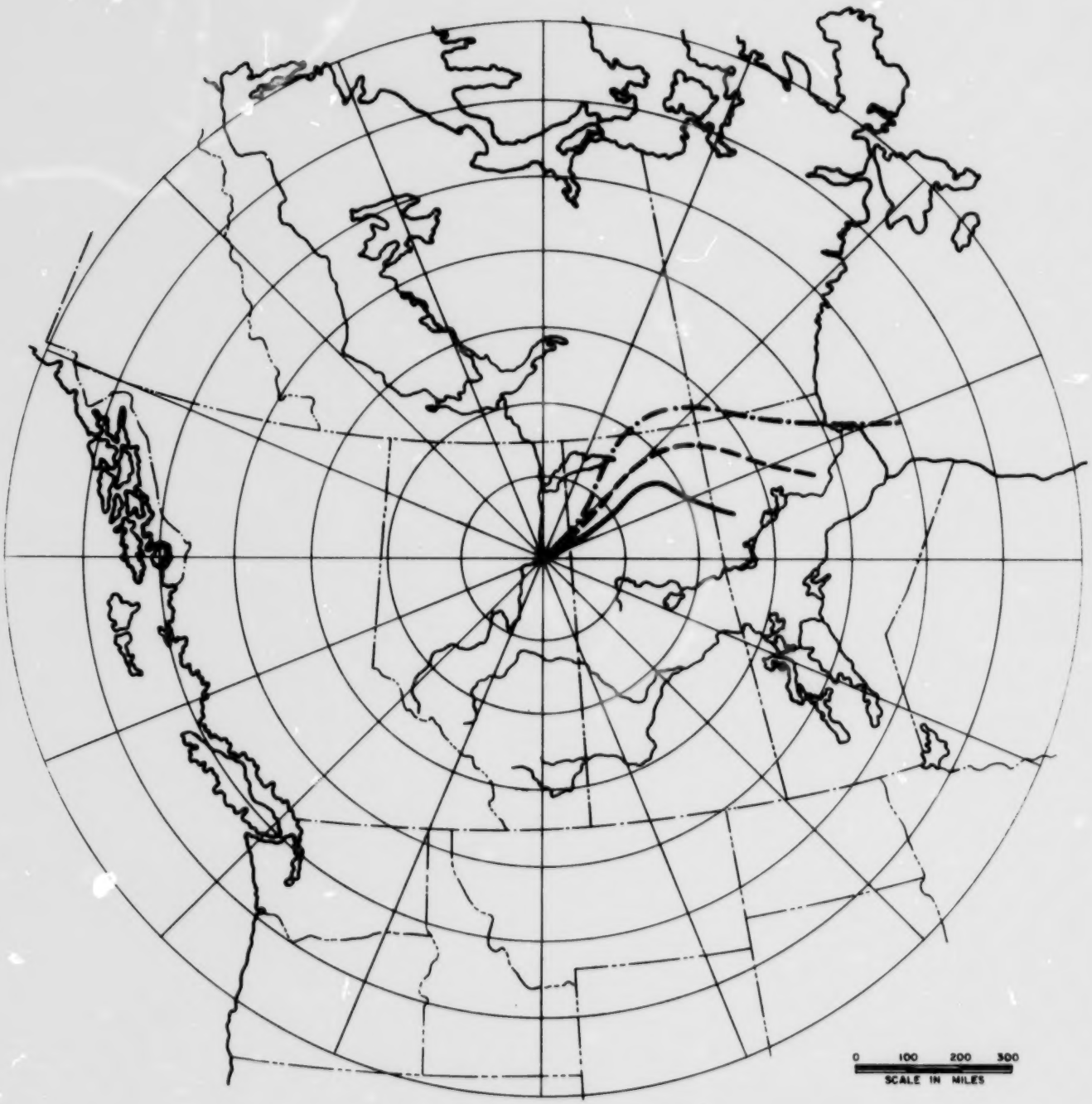
850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - MAY 7, 1973
DIRECTION - IN TO STUDY AREA

NOVEMBER 1976 | FIGURE 7



LEGEND

SURFACE

925 mb

850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - JULY 23, 1974
DIRECTION - OUT FROM STUDY AREA

NOVEMBER 1976 | FIGURE 8

LEGEND

SURFACE

925 mb

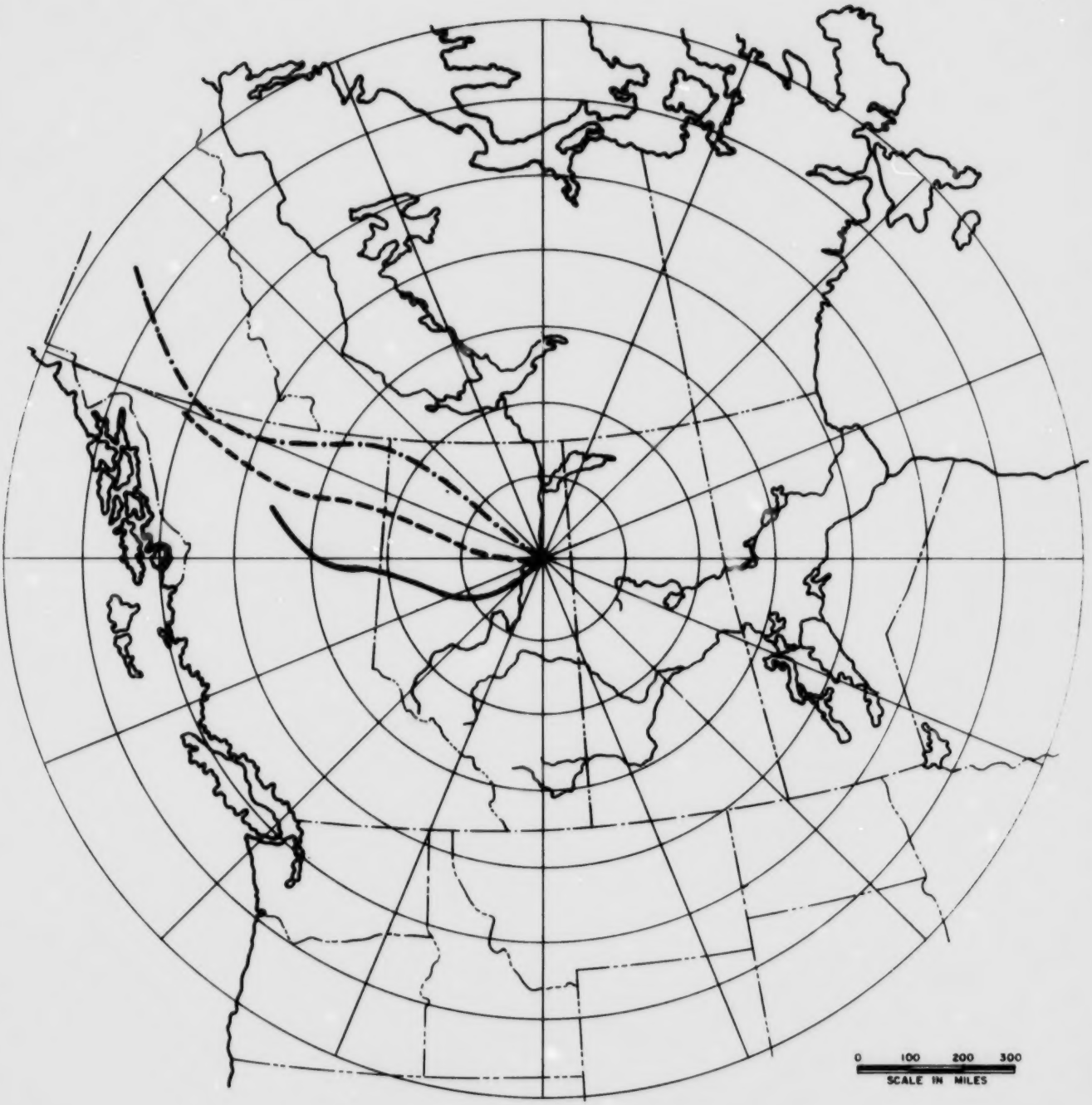
850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - SEPTEMBER 8, 1974
DIRECTION - IN TO STUDY AREA

NOVEMBER 1976 | FIGURE 9



LEGEND

SURFACE

925 mb

850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - FEBRUARY 24, 1975
DIRECTION - IN TO STUDY AREA

NOVEMBER 1976 | FIGURE 10

LEGEND

SURFACE

925 mb

850 mb

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

EXAMPLE TRAJECTORY
72 HOUR ENDING
0000 GMT - DECEMBER 10, 1975
DIRECTION - OUT FROM STUDY AREA

NOVEMBER 1976 | FIGURE 11

5 - FREQUENCY ANALYSIS

5.1 - Analytical Procedures

The 72-hour trajectories were grouped according to four conditions of precipitation during the 72-hour period; these were nil, trace to .25 inch (light), .26 to .50 inch (moderate), over .50 inch (heavy), based on measurements at the Fort McMurray Weather Office. Each 72-hour trajectory map was overlaid with a transparency on which sectors defined by 22.5-degree quadrants and incremental 150-mile radii circles from the study area were labeled. Each time that an air parcel on a trajectory moved through any labeled sector was noted.

The number of occurrences of air parcels in each sector were summed by precipitation groups to give monthly frequencies for each of the 4 years studied, 1968-1973-1974-1975. The monthly frequencies were also summed by precipitation groups to give the annual total for 1968 alone and the 3-year total for 1973-1974-1975, for comparative purposes, in order to assess the climatological stability of the 4-year data base.

The seasonal frequencies were then summed by precipitation groups to give the annual totals for the entire 4-year study period.

Finally the monthly frequencies were summed to give seasonal values by precipitation groups for the total of the 4 study years, where seasons were defined as: December-January-February, March-April-May, June-July-August, September-October-November.

The results of these analyses are shown in map form as isolines of frequency of occurrence (motion) of air parcels by direction and distance from the study area in Subsections 5.2, 5.3 and 5.4 following. The isolines have been drawn so that the numbers plotted in each sector apply at the geometric center of that sector. It should be noted that in the inner ring the numbers are positioned nearer the outside of the sectors to avoid overcrowding; this gives the casual appearance of incorrect contouring which is not the case.

5.2 - Comparison of 1968 and 1973-1974-1975 Total Annual Frequencies

Figures 12 to 19 show the annual air parcel frequency patterns in 1968 and the sum of those over the three year period 1973-1974-1975, at the surface and 850-mb levels, for the conditions of nil precipitation and light precipitation, and for trajectories in to the study area.

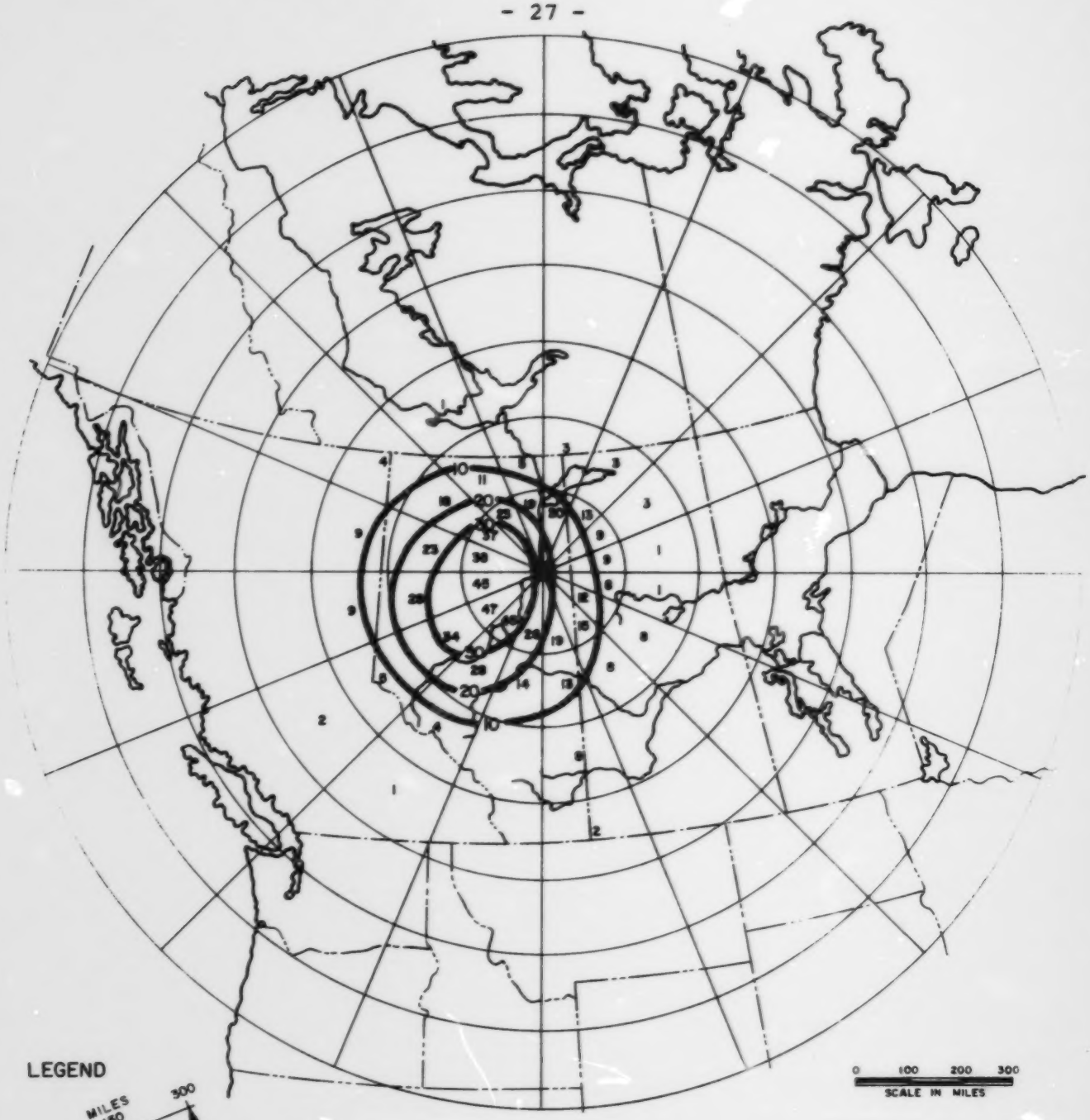
For the case of nil precipitation, the patterns are similar with higher frequencies in the general westerly quadrant at both the surface and 850-mb levels. The maximum frequency at the surface shifts from the southwest for the 1973-1974-1975 period to about south-southwest in 1968. At the 850-mb level, the maximum frequency for the 1973-1974-1975 period is from the west-northwest and in 1968 is west-northwest to west-southwest.

For the case of light precipitation, the patterns are very similar, with highest frequencies in the general westerly quadrant at both the surface and 850-mb levels. The

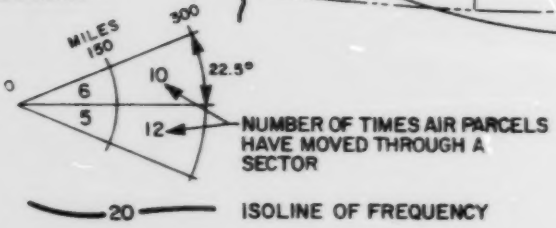
maximum frequency at the surface again shifts from about west-southwest for the 1973-1974-1975 period to south-southwest in 1968. At the 850-mb level, the maximum frequency is from the west-northwest both in the 1973-1974-1975 period and in 1968.

Since the dominant trajectory directions differ by not more than 45 degrees in the data sets for 1968 and 1973-1974-1975, that is by half the criterion selected (see page 5), it is concluded that the results of frequency analyses made on the 4-year totals for 1968-1973-1974-1975 should reasonably approach climatological stability for the 72-hour air trajectory parameter under study. Also of interest is the secondary component from the south to southeast at the surface level in both sets of data.

COMPARISON OF 1968 AND 1973-1974-
1975 TOTAL ANNUAL FREQUENCIES



LEGEND



LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

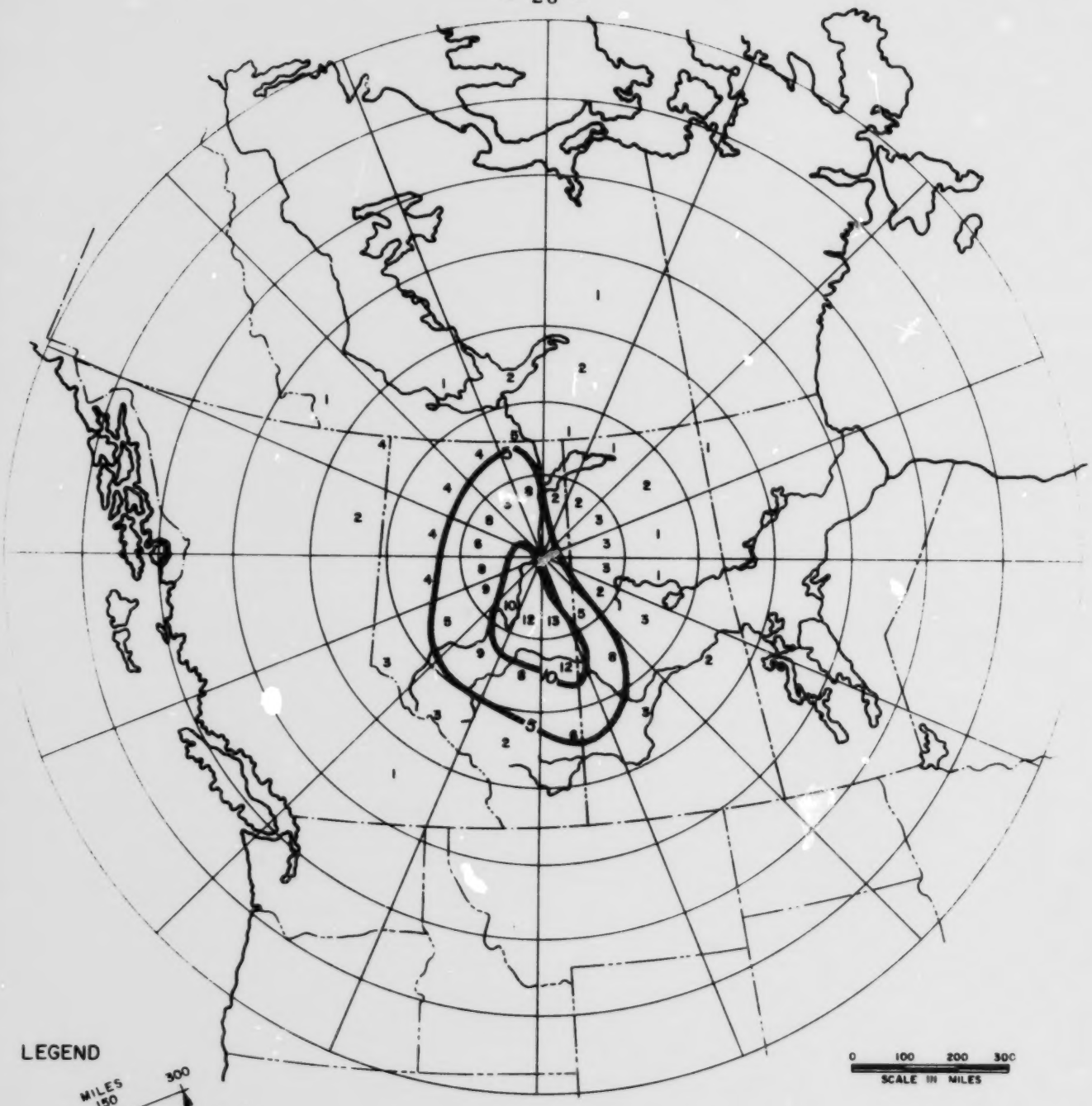
PERIOD – 1973, 74, 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 12



LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

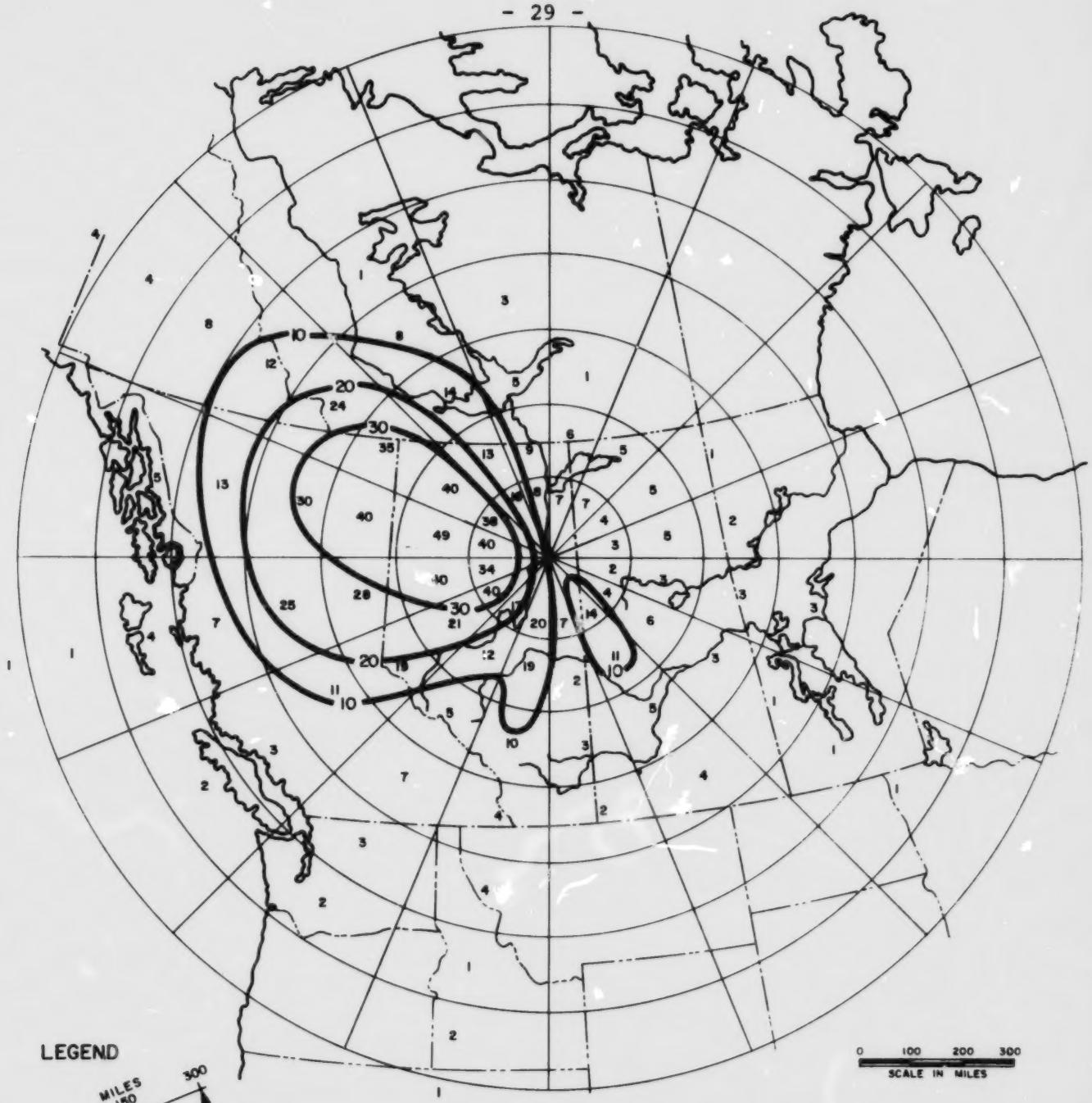
PERIOD – 1968 ANNUAL TOTAL

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 13



LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

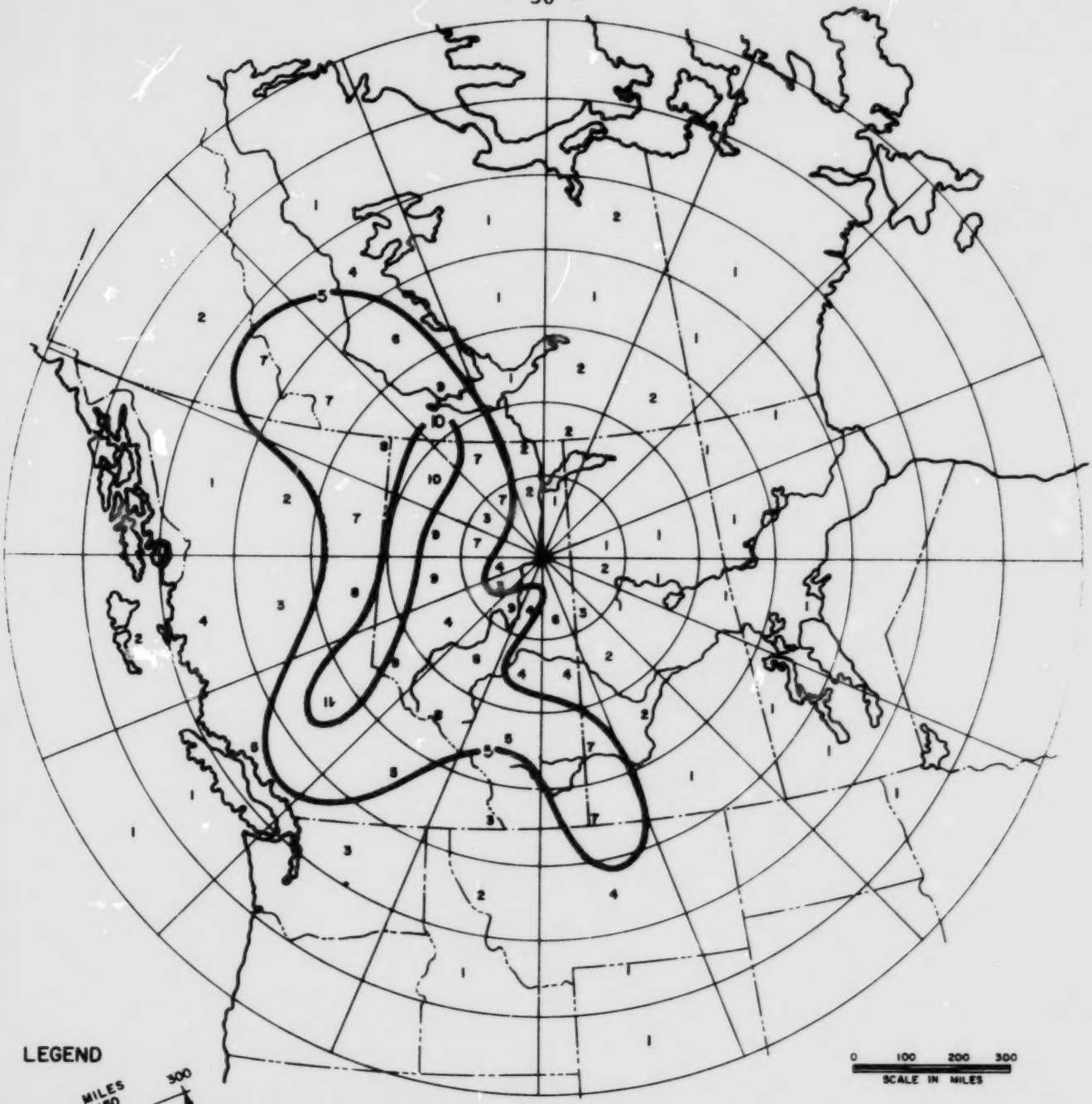
PERIOD – 1973, 74, 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

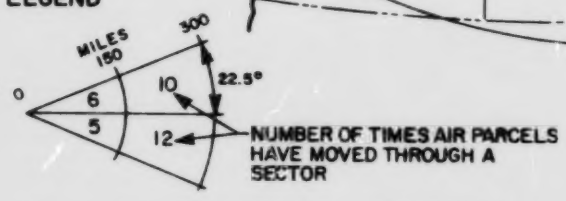
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 14



LEGEND



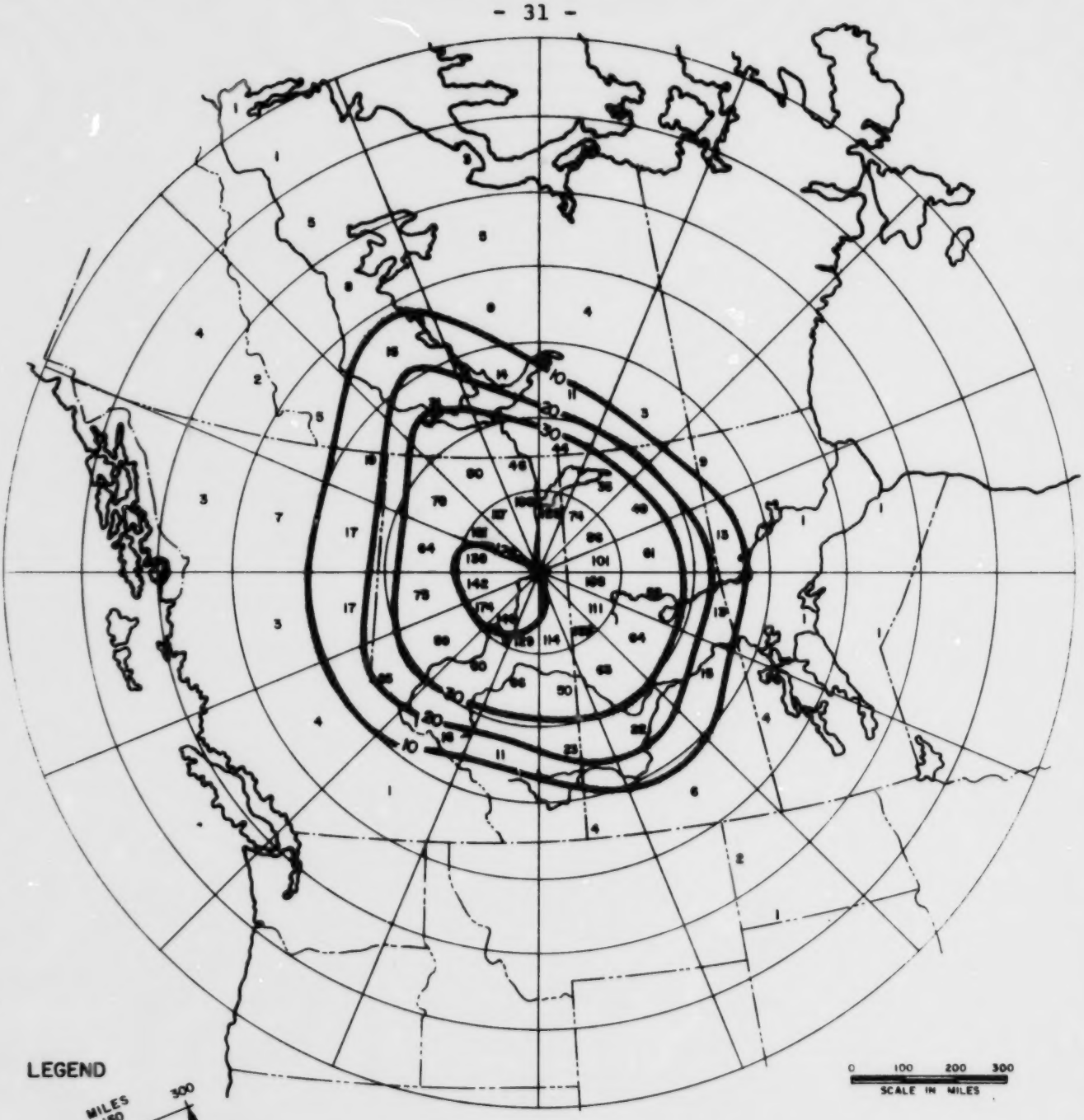
LEVEL – 850 mb
72 HOUR PRECIPITATION – NIL
DIRECTION – IN TO STUDY AREA
PERIOD – 1968 ANNUAL TOTAL

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 15



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

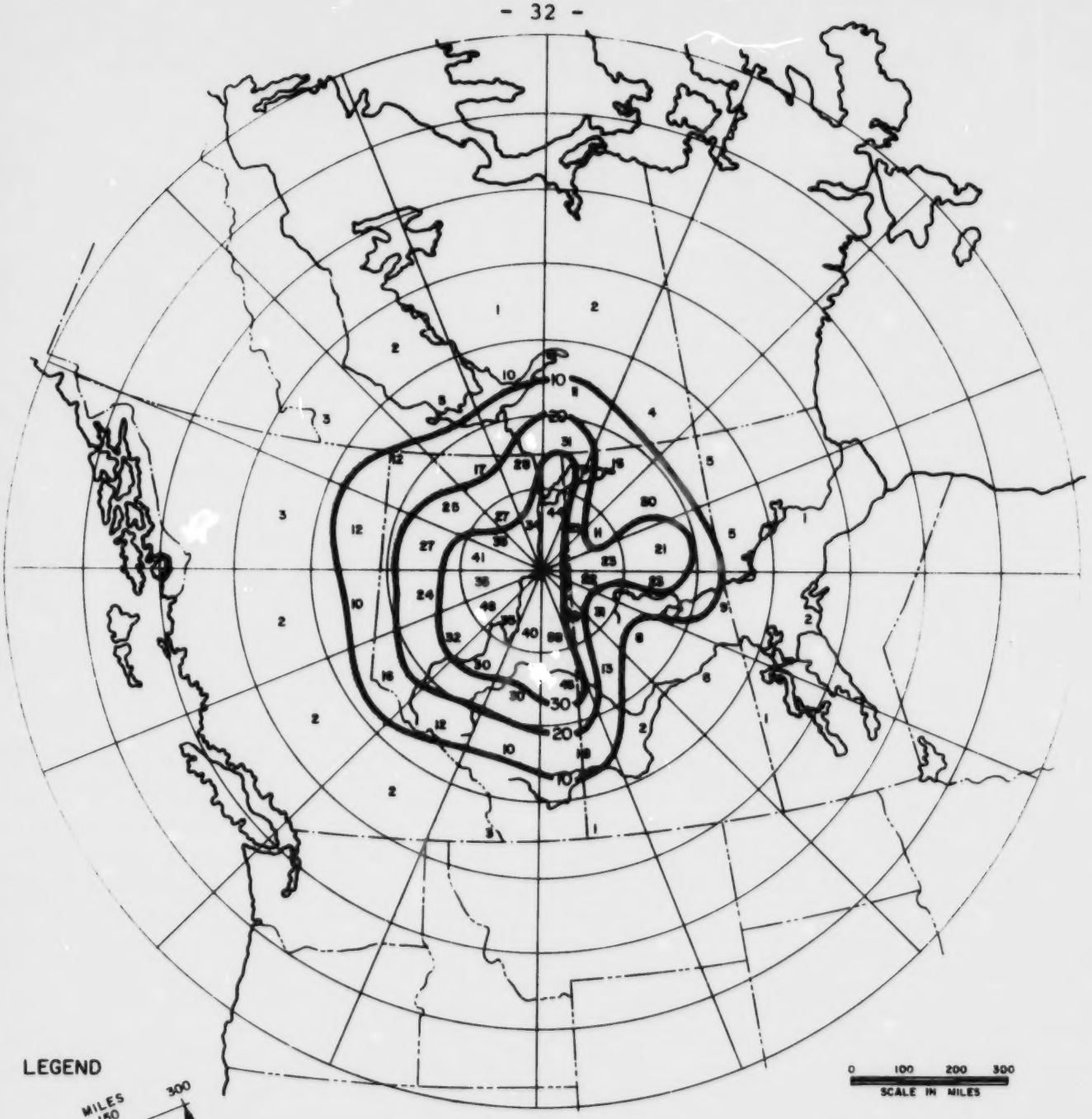
PERIOD – 1973, 74, 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 16



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

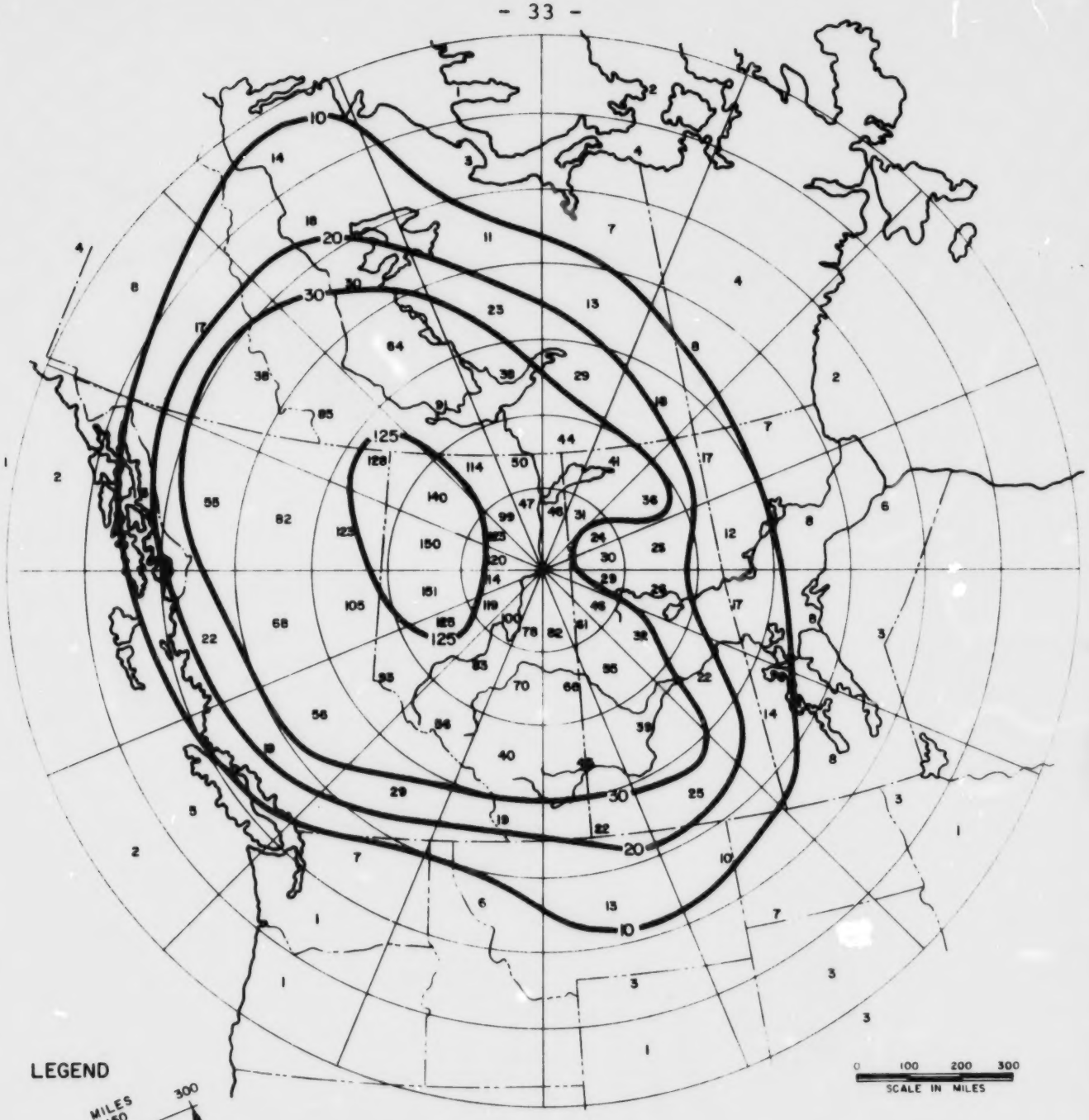
PERIOD – 1968 ANNUAL TOTAL

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

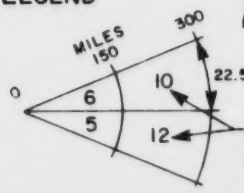
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 17



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR

20 — ISOLINE OF FREQUENCY

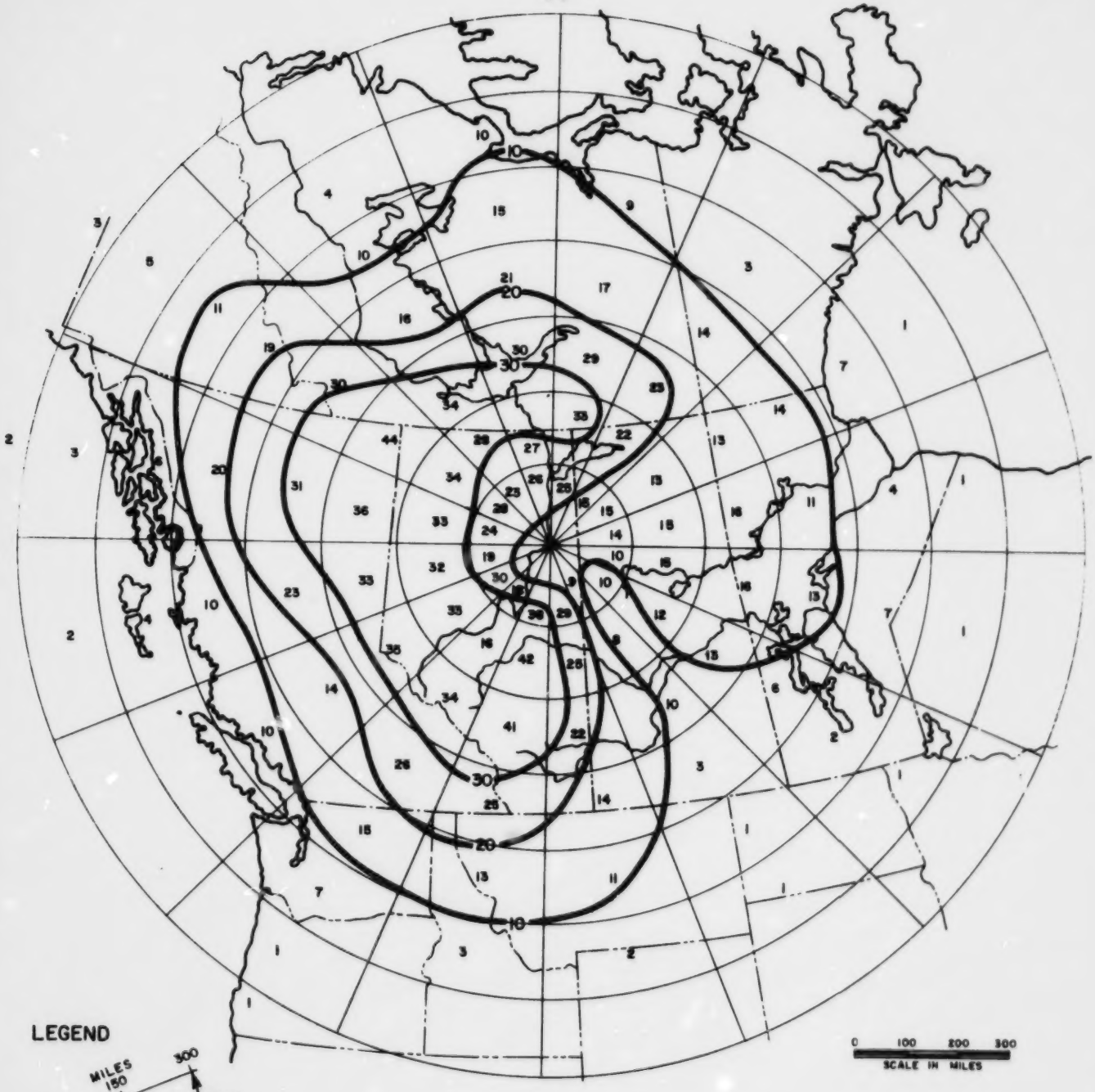
LEVEL – 850 mb
72 HOUR PRECIPITATION – LIGHT
DIRECTION – IN TO STUDY AREA
PERIOD – 1973, 74, 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 18



LEVEL – 850 mb
72 HOUR PRECIPITATION – LIGHT
DIRECTION – IN TO STUDY AREA
PERIOD – 1968 ANNUAL TOTAL

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 19

5.3 - Total Annual Frequencies for the 4-year Study Period

Figures 20 to 43 show the annual patterns of frequency of air parcel motions, summed over the 4 years, 1968-1973-1974-1975, for four precipitation conditions, nil-light-moderate-heavy, as previously defined, at three levels, surface-925 mb-850 mb. These are discussed by precipitation conditions.

In the case of nil precipitation over the 72-hour trajectory period, the patterns are consistent at all three levels for air parcels moving both in to and out from the study area. The dominant frequencies for motions in to the study area are from northwest to southwest at all three levels, with frequencies increasing in distance from the study area with increasing height, and thus increasing wind speeds. The dominant frequencies for motions out from the study area are to northeast to southeast at all three levels, with the frequencies again increasing in distance from the study area with height. There are secondary components from the south-southeast for air moving in to the study area and to the north-northwest for air moving out from the study area.

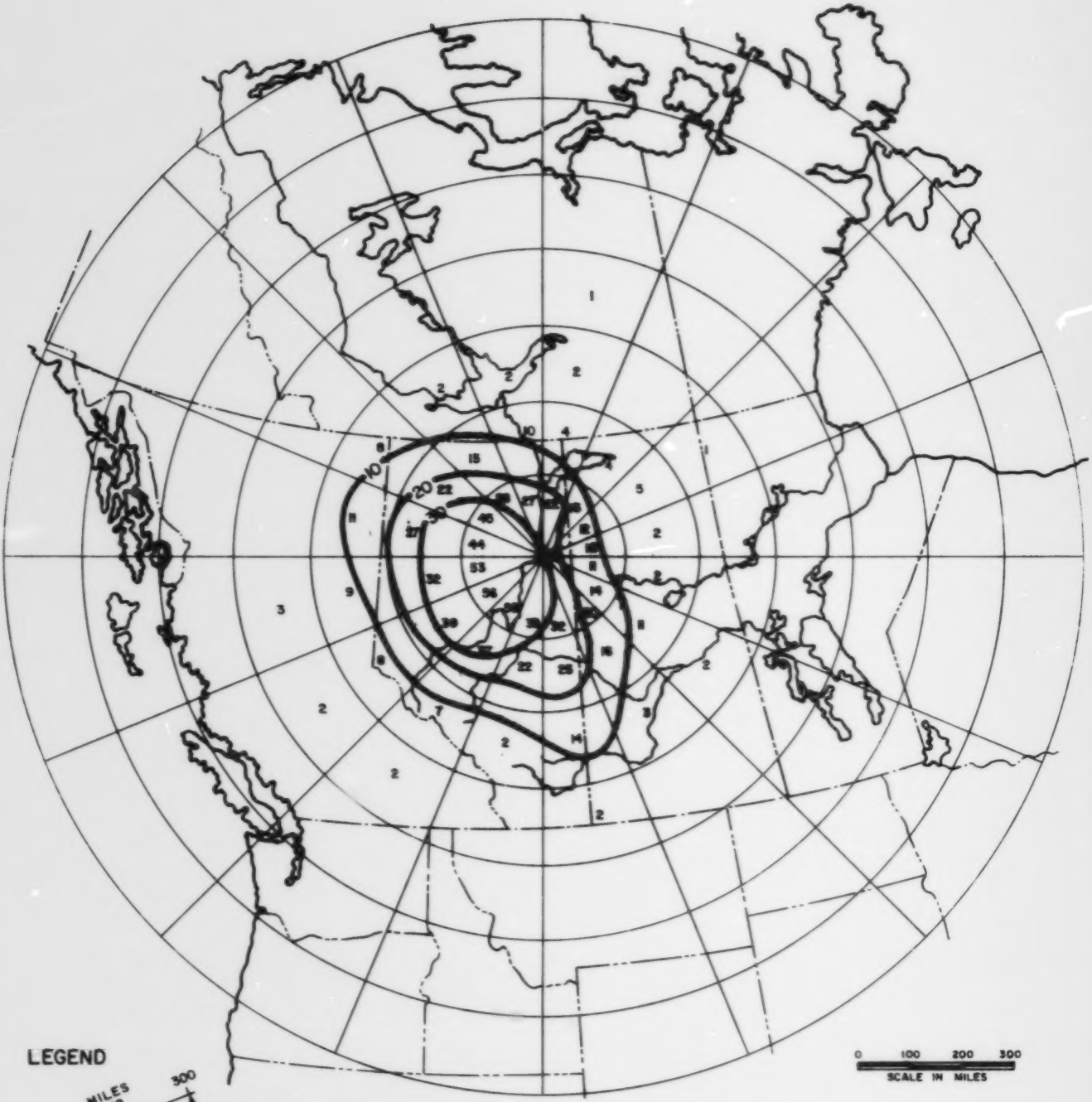
In the case of light precipitation, the frequency distribution patterns also are consistent at all three levels for air parcels moving both in to and out from the study area. The dominant frequencies for motions in to the study area are from the west southwest at the surface level, the west at 925 mb and the west-northwest at 850 mb. For air parcel motions out from the study area, the dominant frequencies are to the east at the surface level, to the north-northwest and east-southeast at 925 mb and to the east-southeast at 850 mb.

In the case of moderate precipitation, the frequency distribution patterns at the surface level do not show any dominant directional bias for air parcel motions in to and out from the study area, although there is some bias in both cases along a northwest-southeast axis. For motions in to the study area, the dominant frequencies are from the northwest at both 925 and 850 mb. For motions out from the study area, the dominant frequencies are to the southeast at these levels.

In the case of heavy precipitation, there again is no dominant directional bias for air parcel motions in to and out from the study area at any level. For both in and out motions there is a directional bias along a northwest-southeast axis at all levels. For motions in to the study area, there is a second directional bias in the north-northeast direction, and for motions out from the study area in the south-southwest direction at all three levels. At the 850-mb level, the second directional bias seems to tend to a northeast-southwest axis for both motions in to and out from the study area.

TOTAL ANNUAL FREQUENCIES

NIL PRECIPITATION
Surface - 925 mb - 850 mb Levels
In To and Out From Study Area



LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

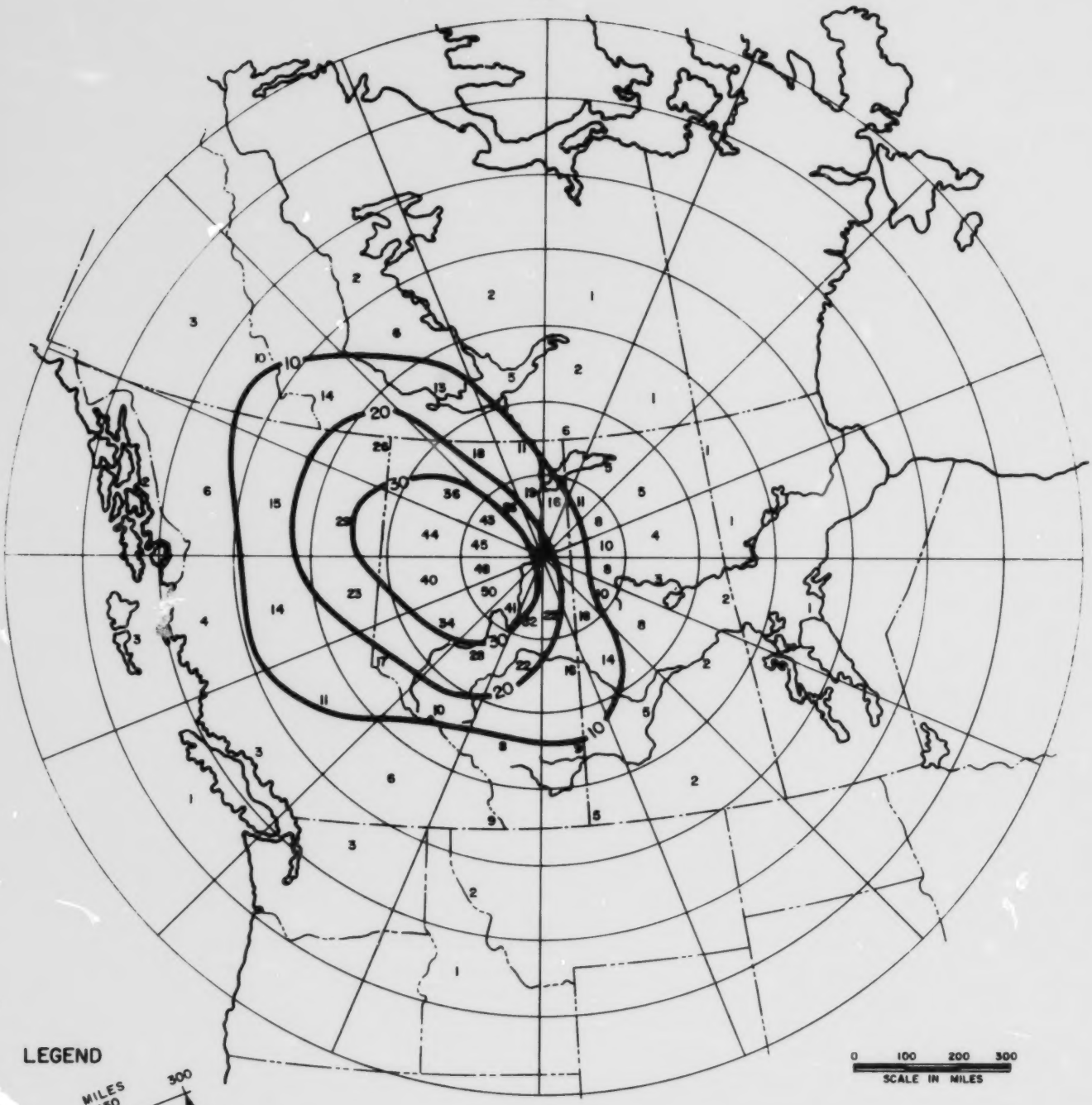
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

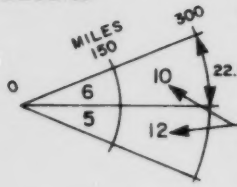
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 20



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 925 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

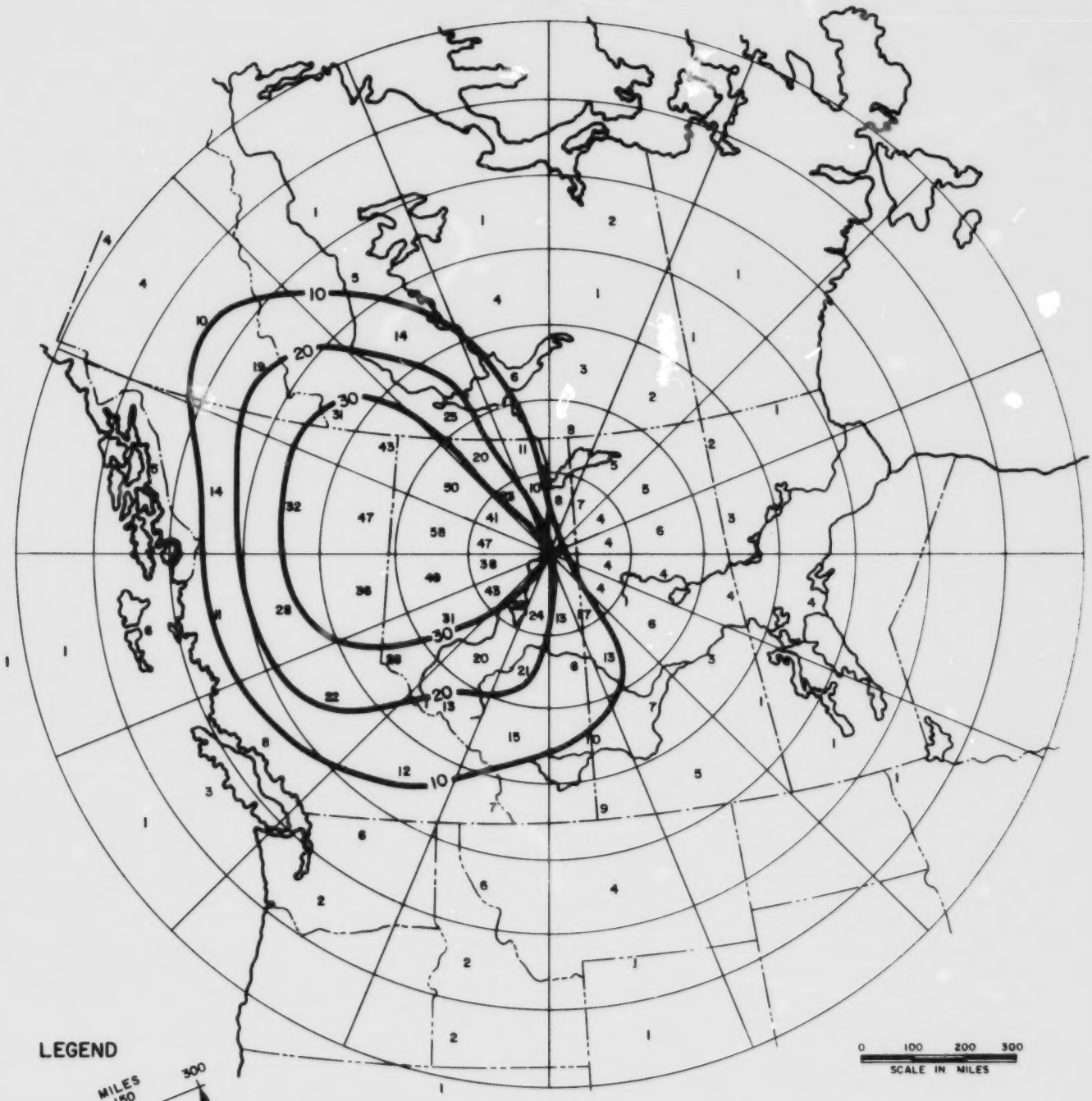
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

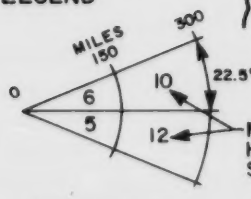
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 21



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

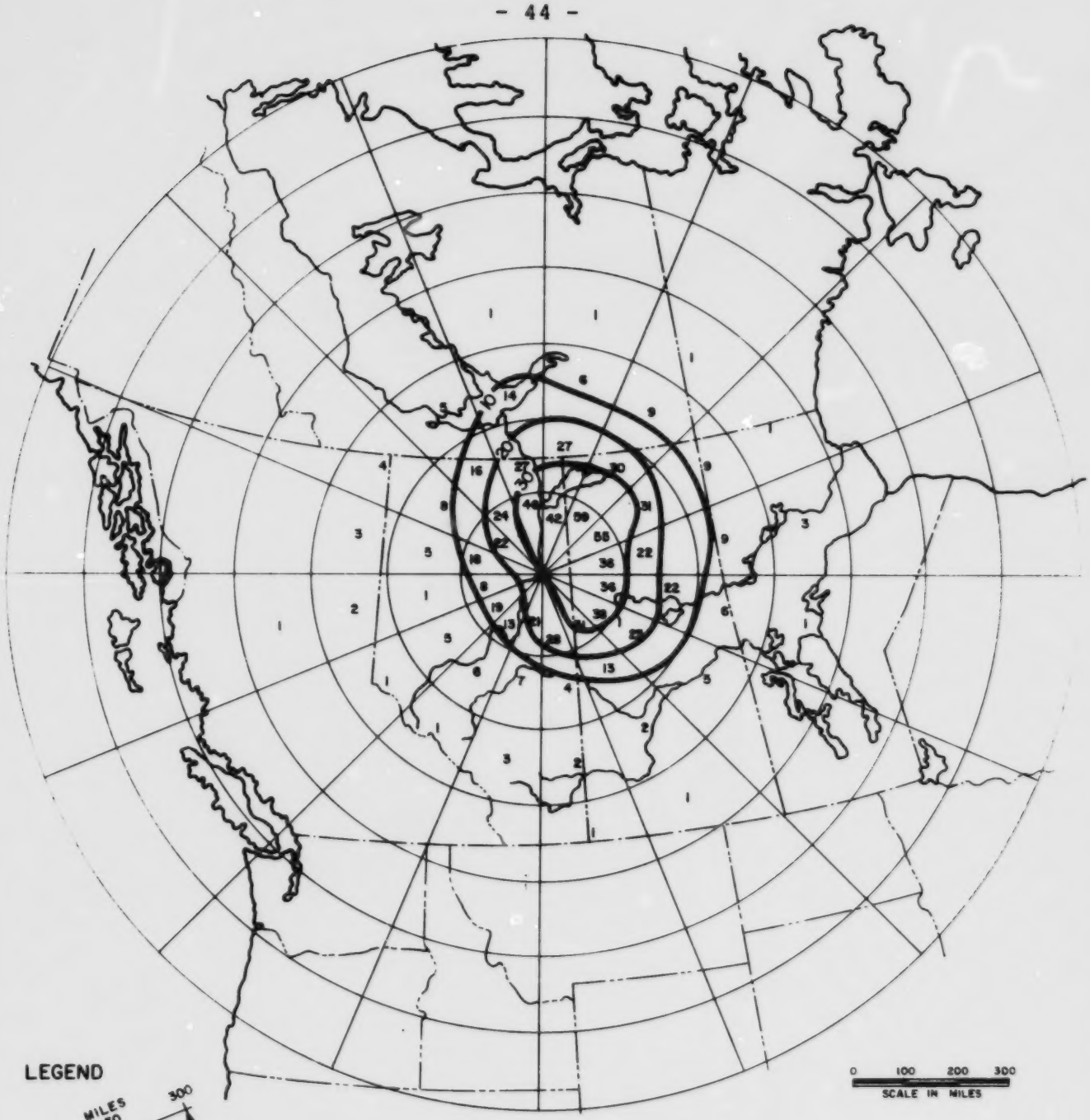
LEVEL – 850 mb
72 HOUR PRECIPITATION – NIL
DIRECTION – IN TO STUDY AREA
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 22



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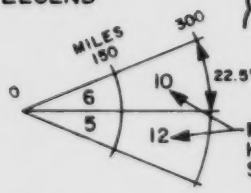


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

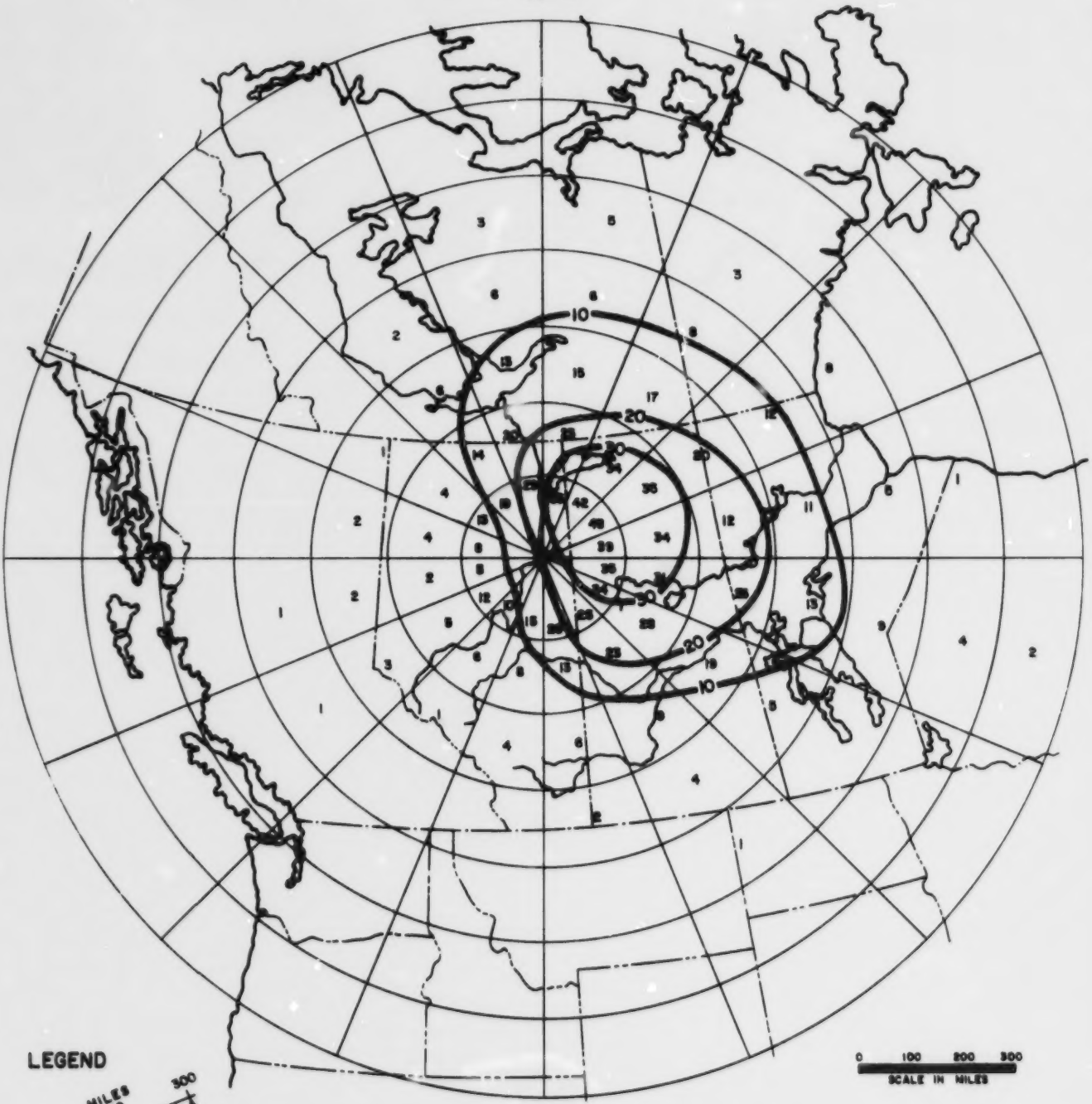
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

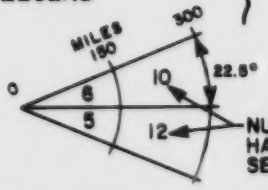
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 23



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 925 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

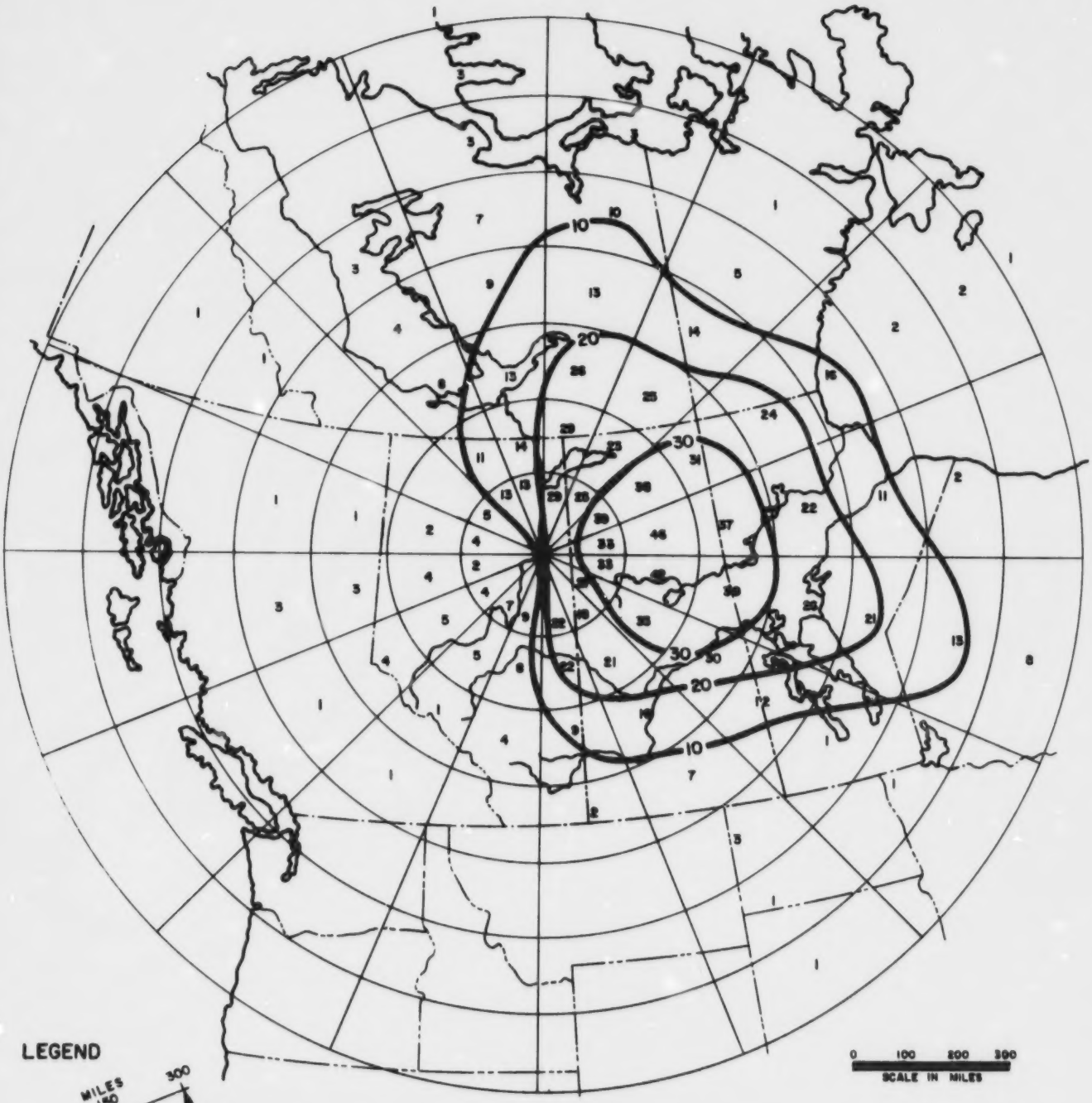
AOSERP

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

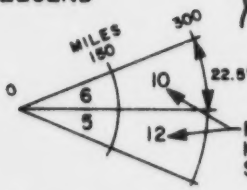
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 24



LEGEND



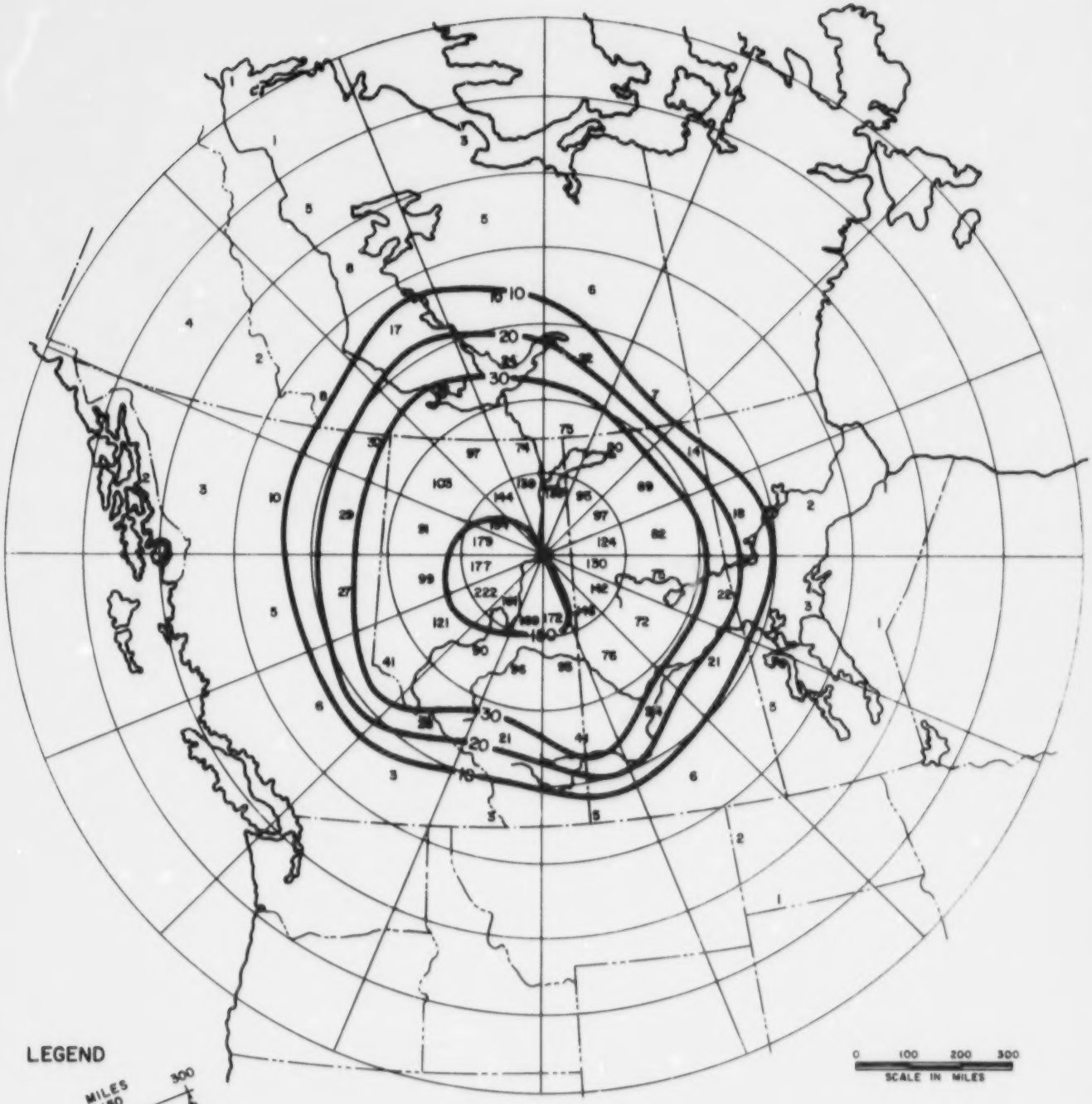
NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

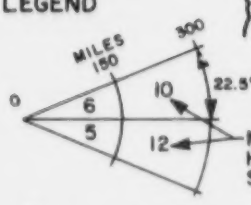
LEVEL – 850 mb
72 HOUR PRECIPITATION – NIL
DIRECTION – OUT FROM STUDY AREA
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

AOSERP	ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
	AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS
FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA	
NOVEMBER 1976	FIGURE 25

LIGHT PRECIPITATION
Surface - 925 mb - 850 mb Levels
In To and Out From Study Area



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

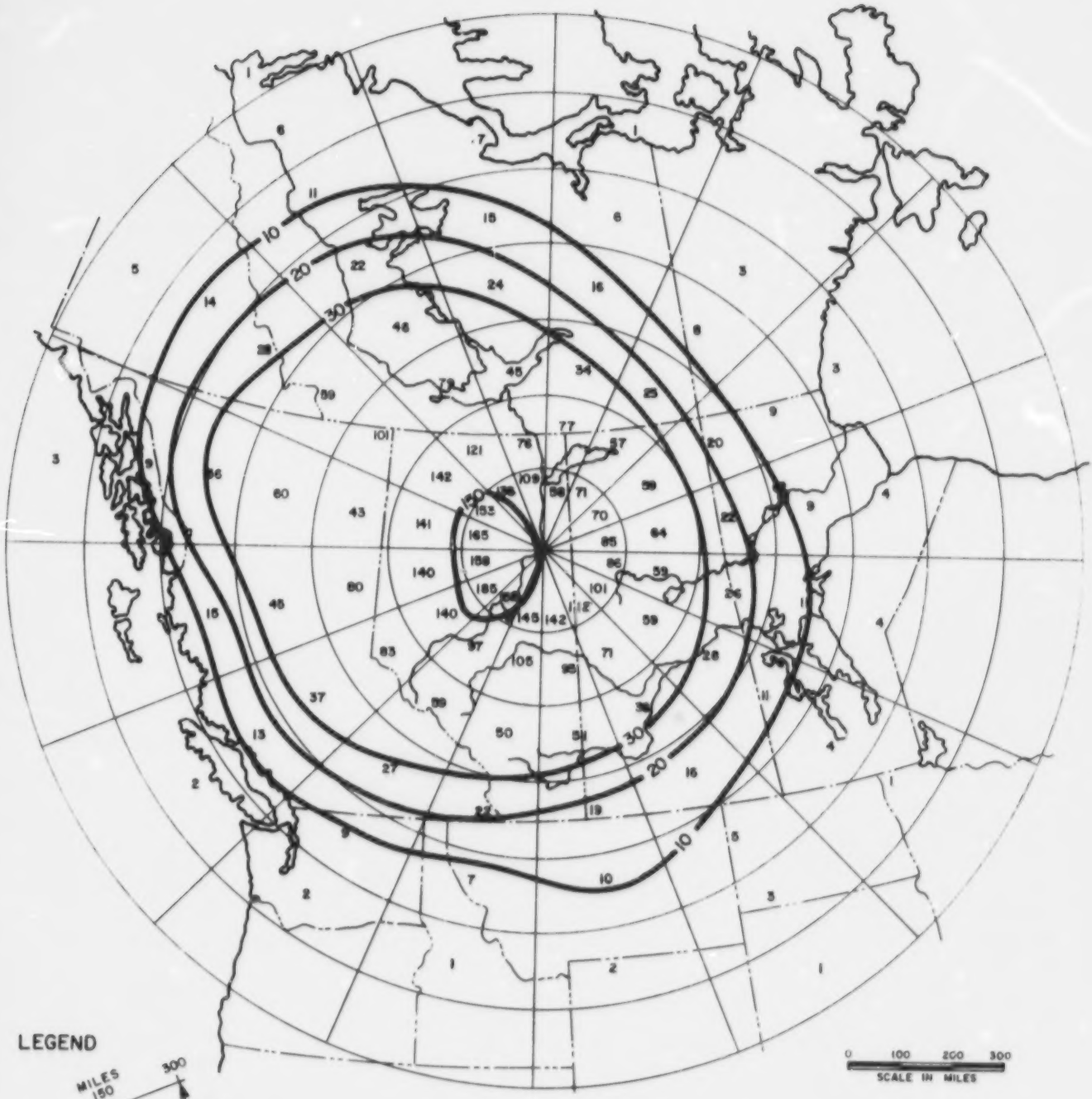
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

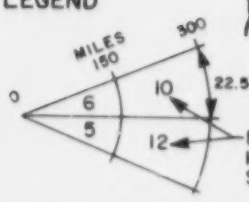
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 26



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

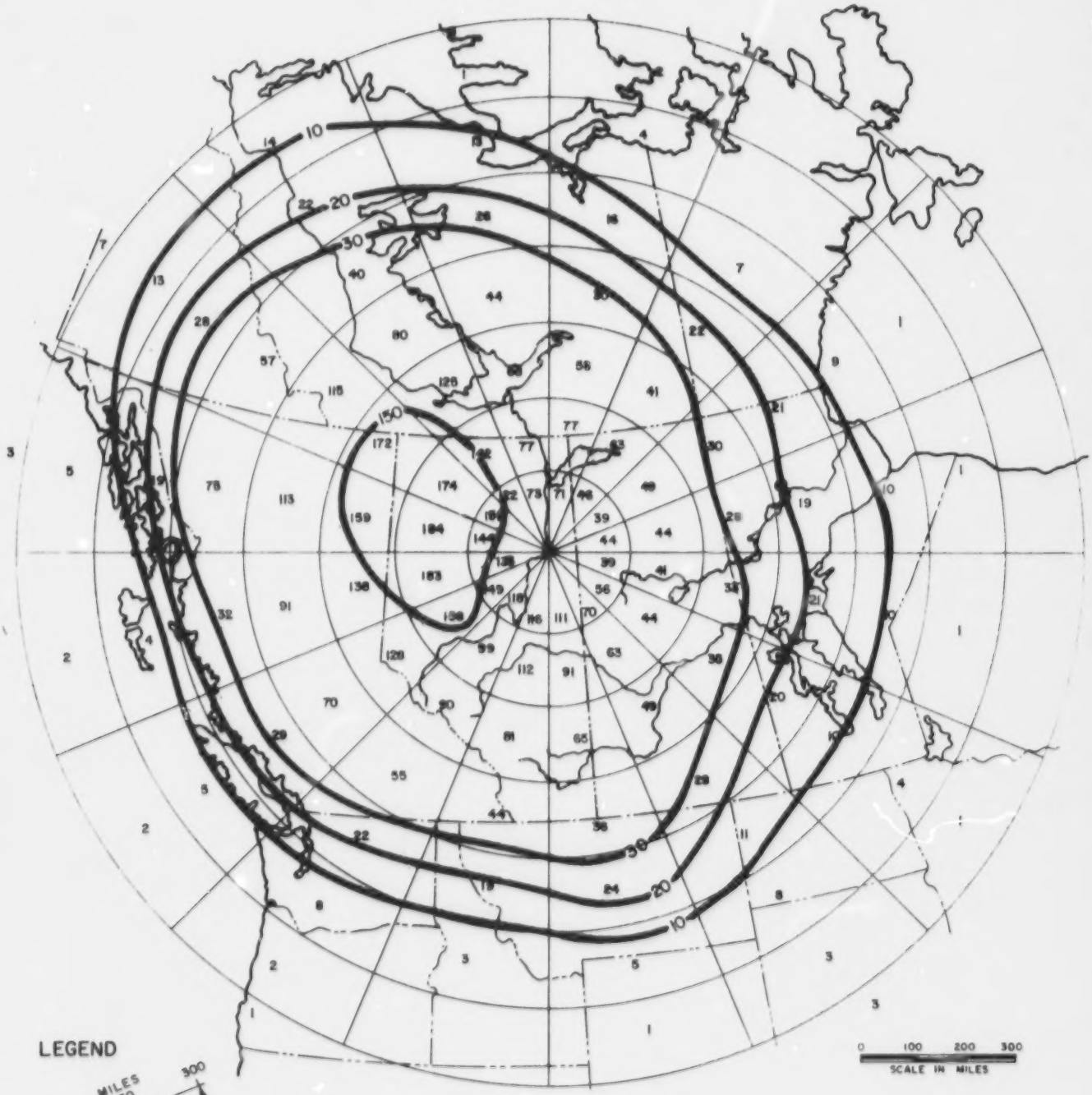
LEVEL – 925 mb

72 HOUR PRECIPITATION – LIGHT

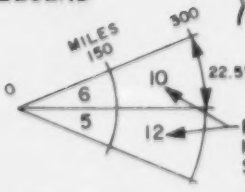
DIRECTION – IN TO STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM	
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS	
FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA	
NOVEMBER 1976	FIGURE 27



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

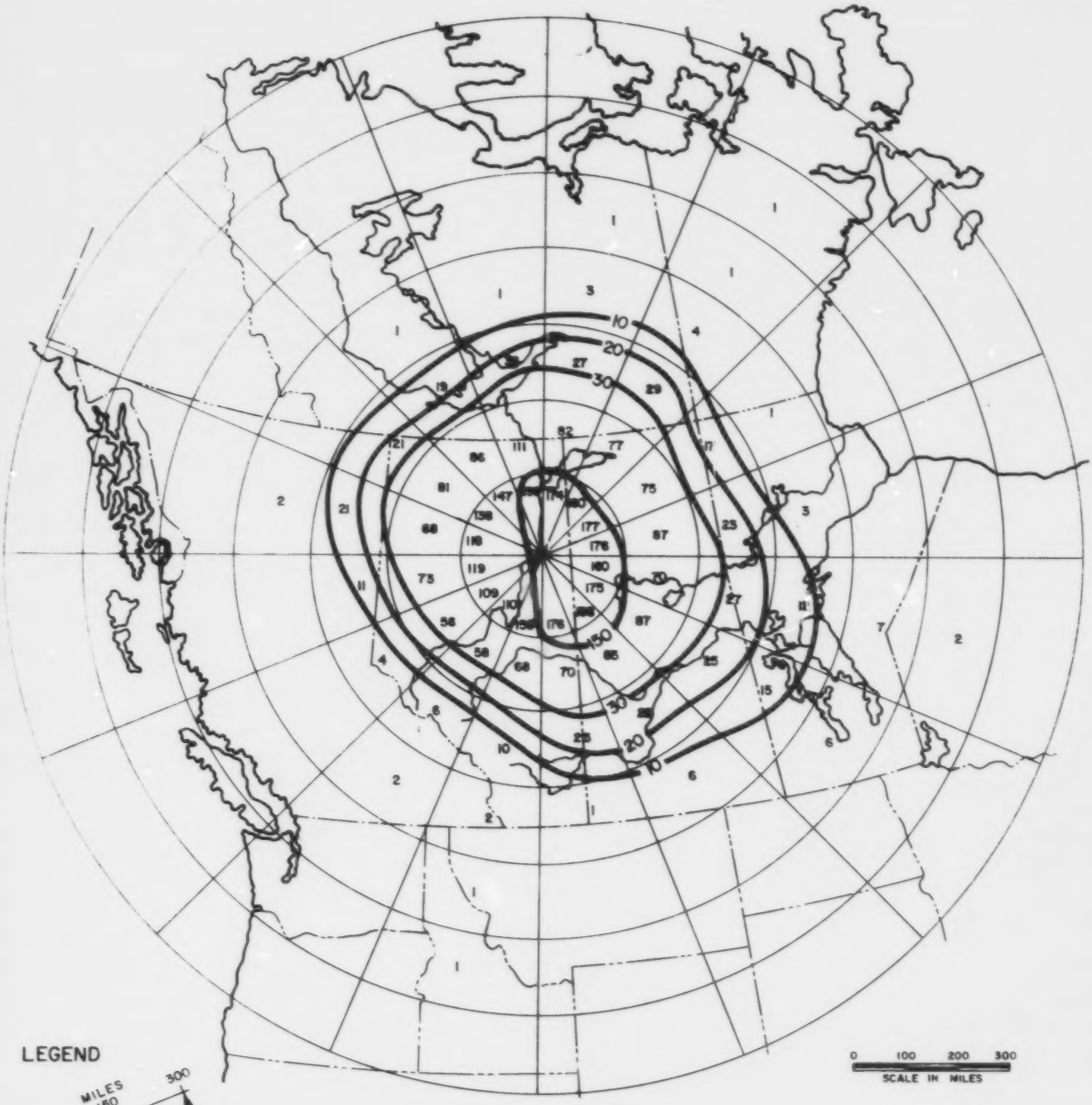
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

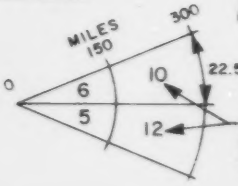
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 28



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

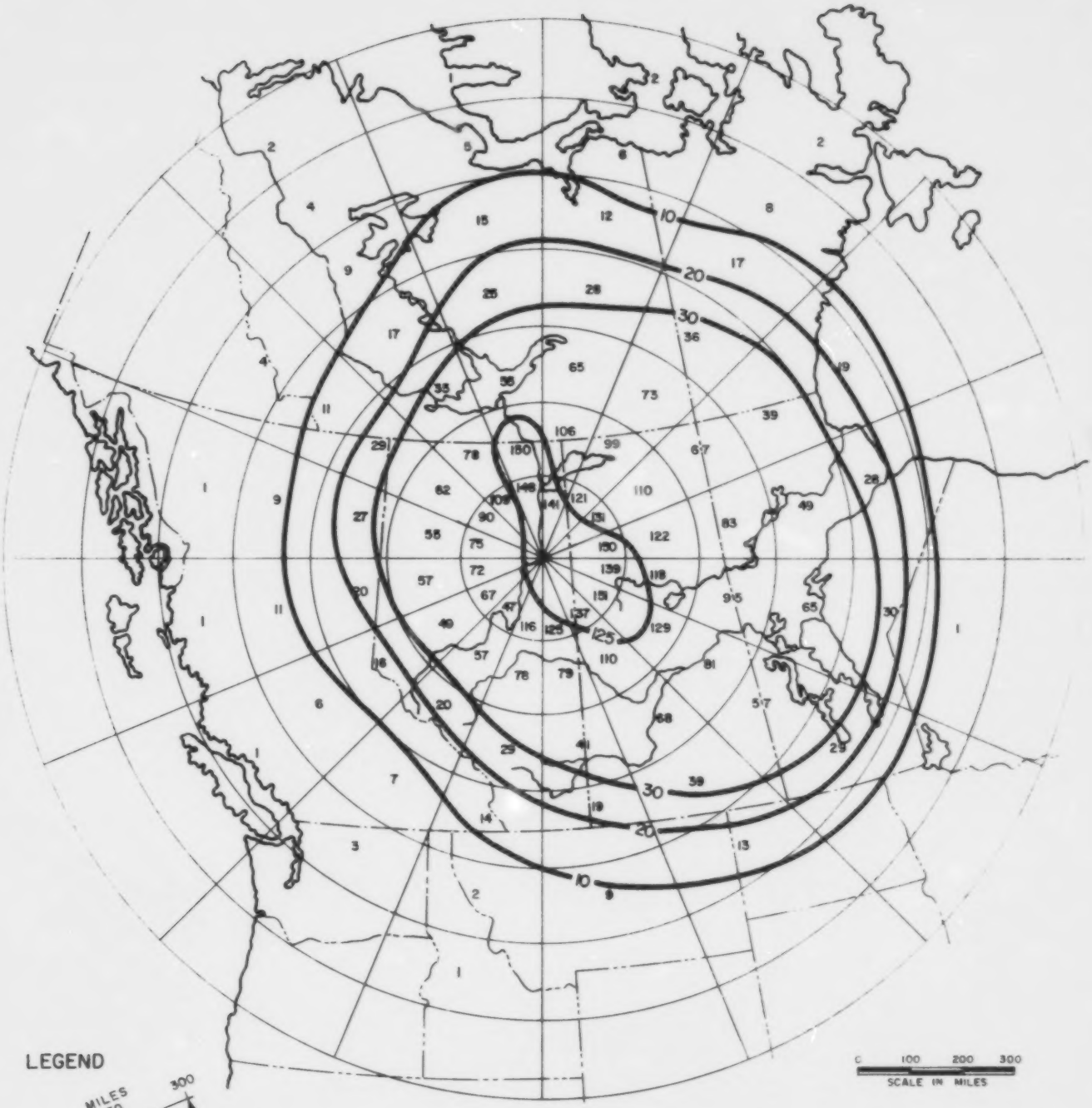
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 29



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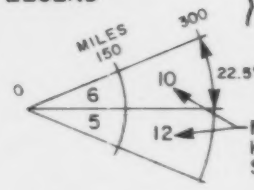


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

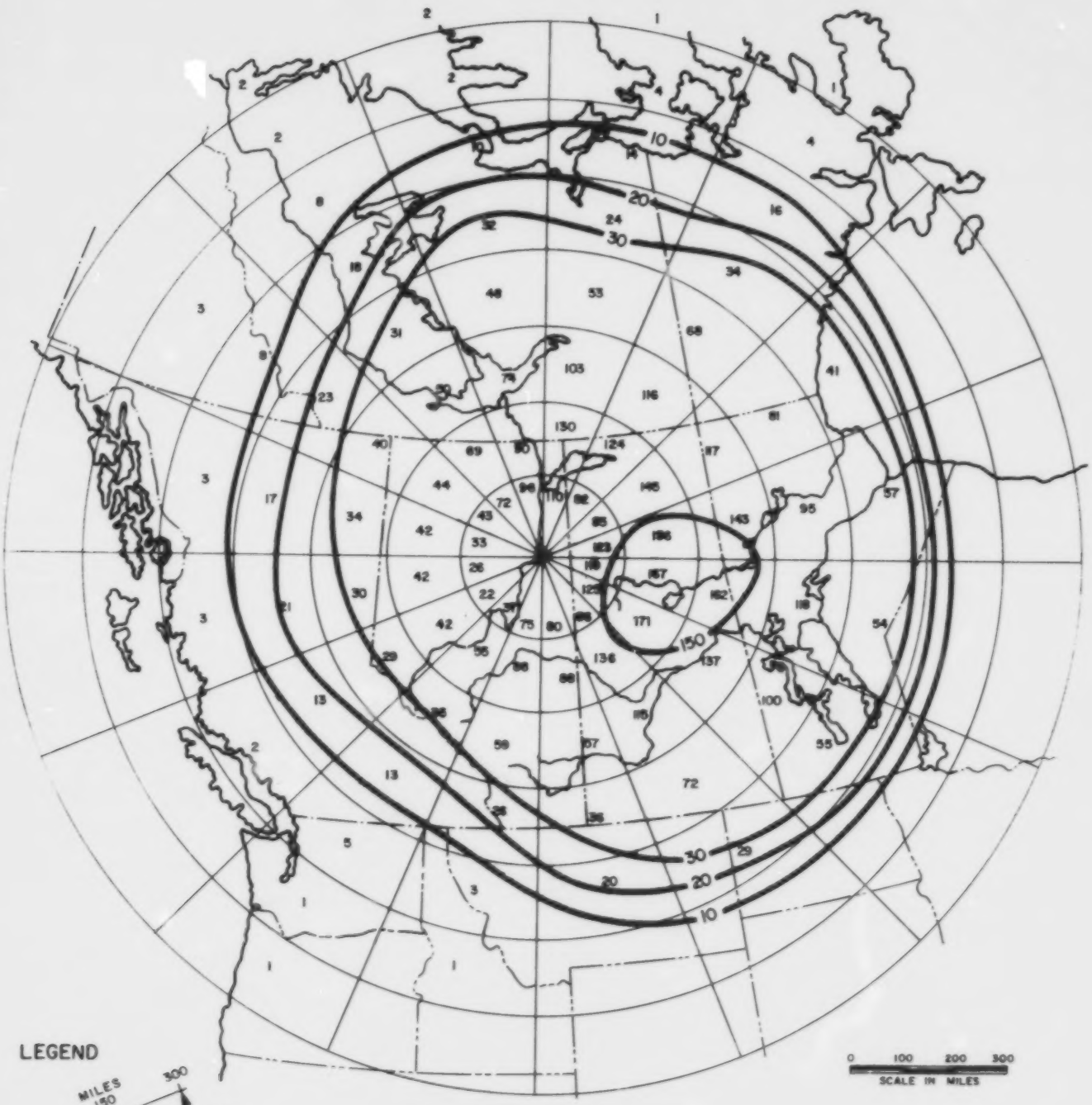
LEVEL – 925 mb

72 HOUR PRECIPITATION – LIGHT

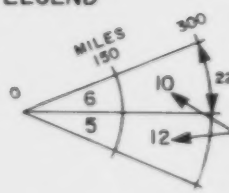
DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ACRES	ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
	AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS
FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA	
NOVEMBER 1976	FIGURE 30



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

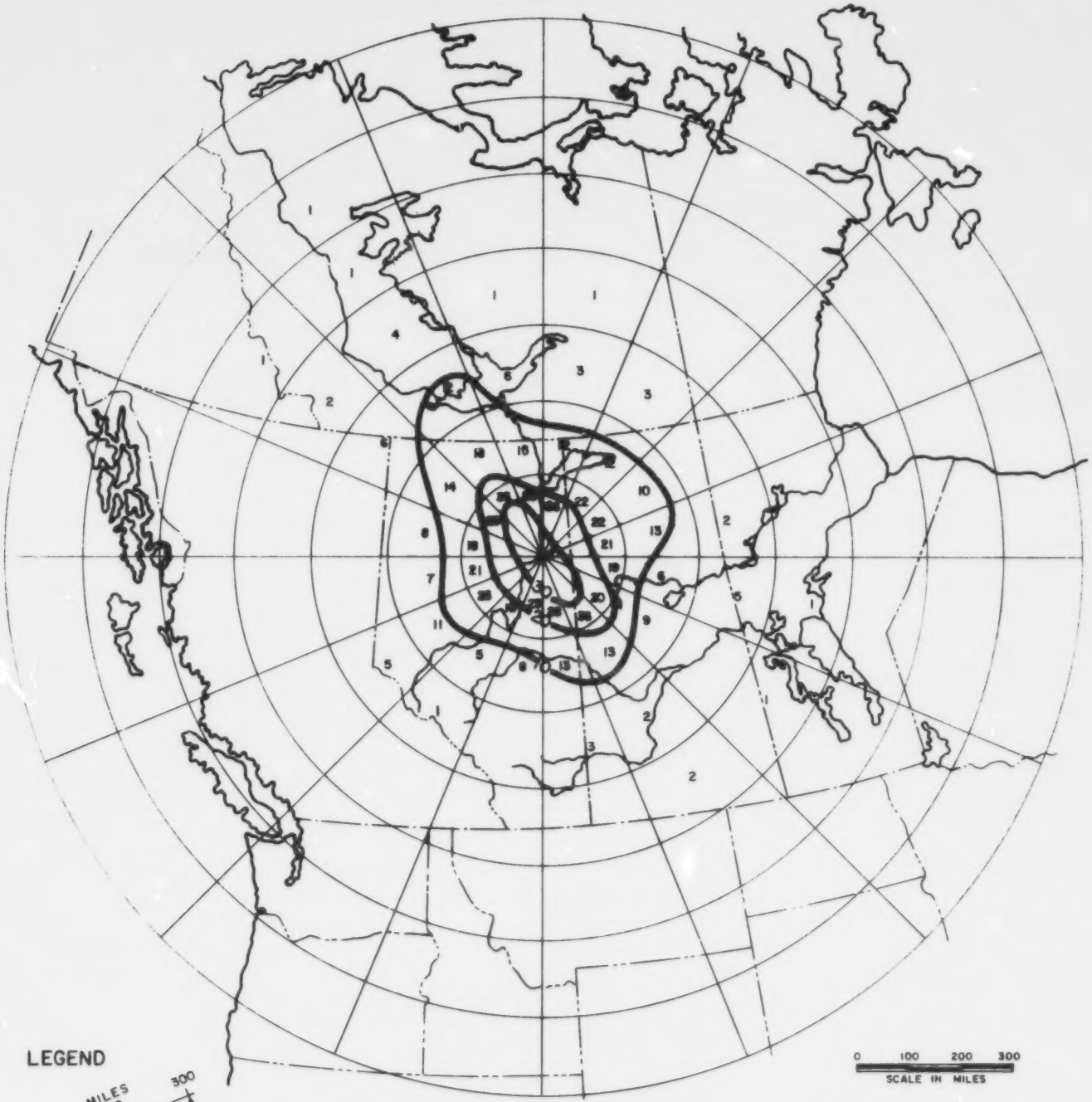
72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

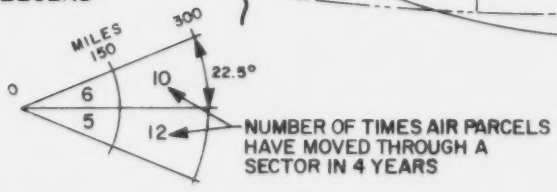
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

AOSERP	ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
	AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS
FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA	
NOVEMBER 1976	FIGURE 31

MODERATE PRECIPITATION
Surface - 925 mb - 850 mb Levels
In To and Out From Study Area



LEGEND



LEVEL – SURFACE

72 HOUR PRECIPITATION – MODERATE

DIRECTION – IN TO STUDY AREA

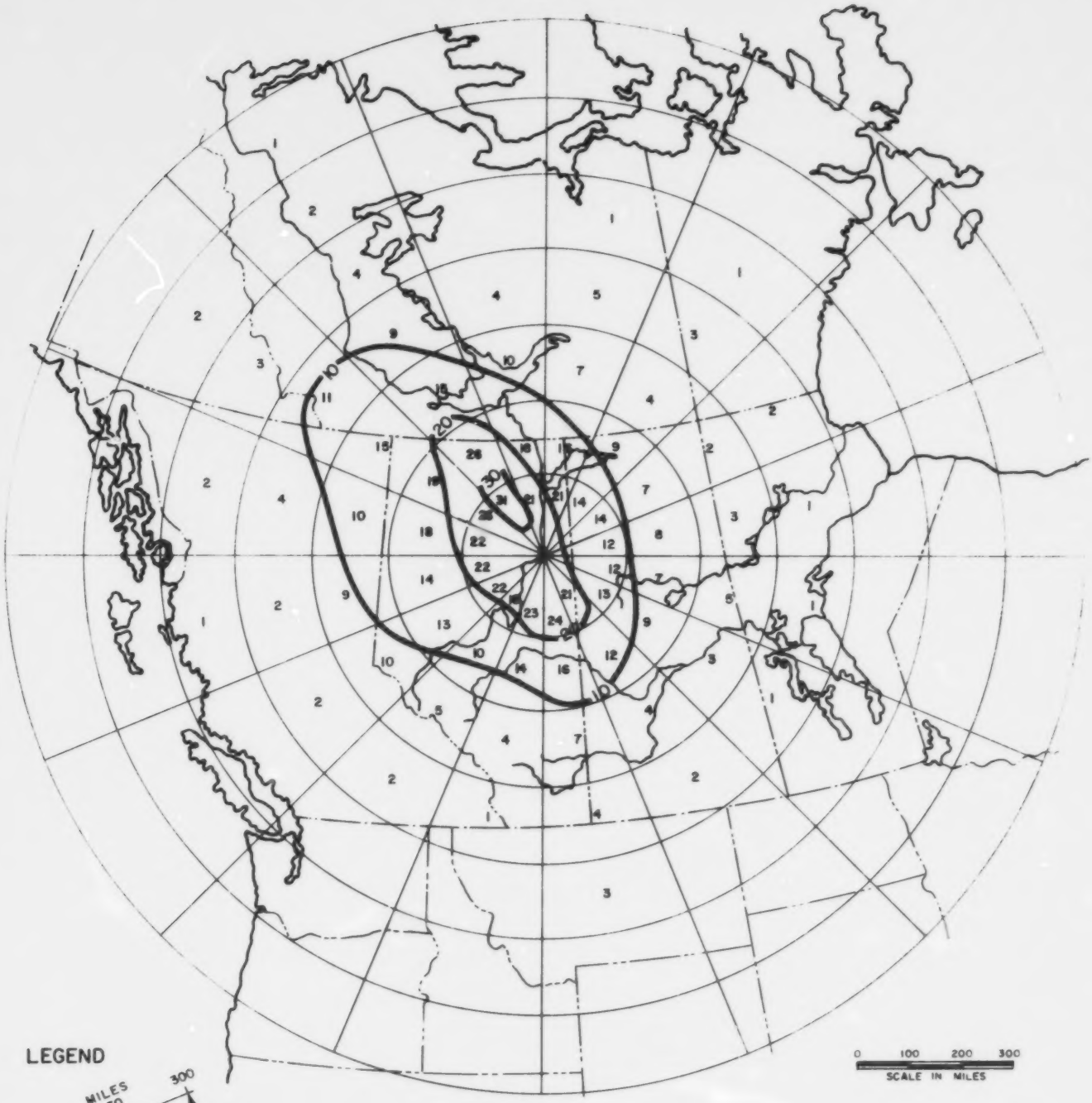
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

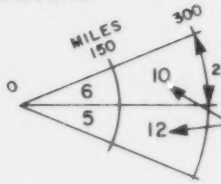
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 32



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 925 mb

72 HOUR PRECIPITATION – MODERATE

DIRECTION – IN TO STUDY AREA

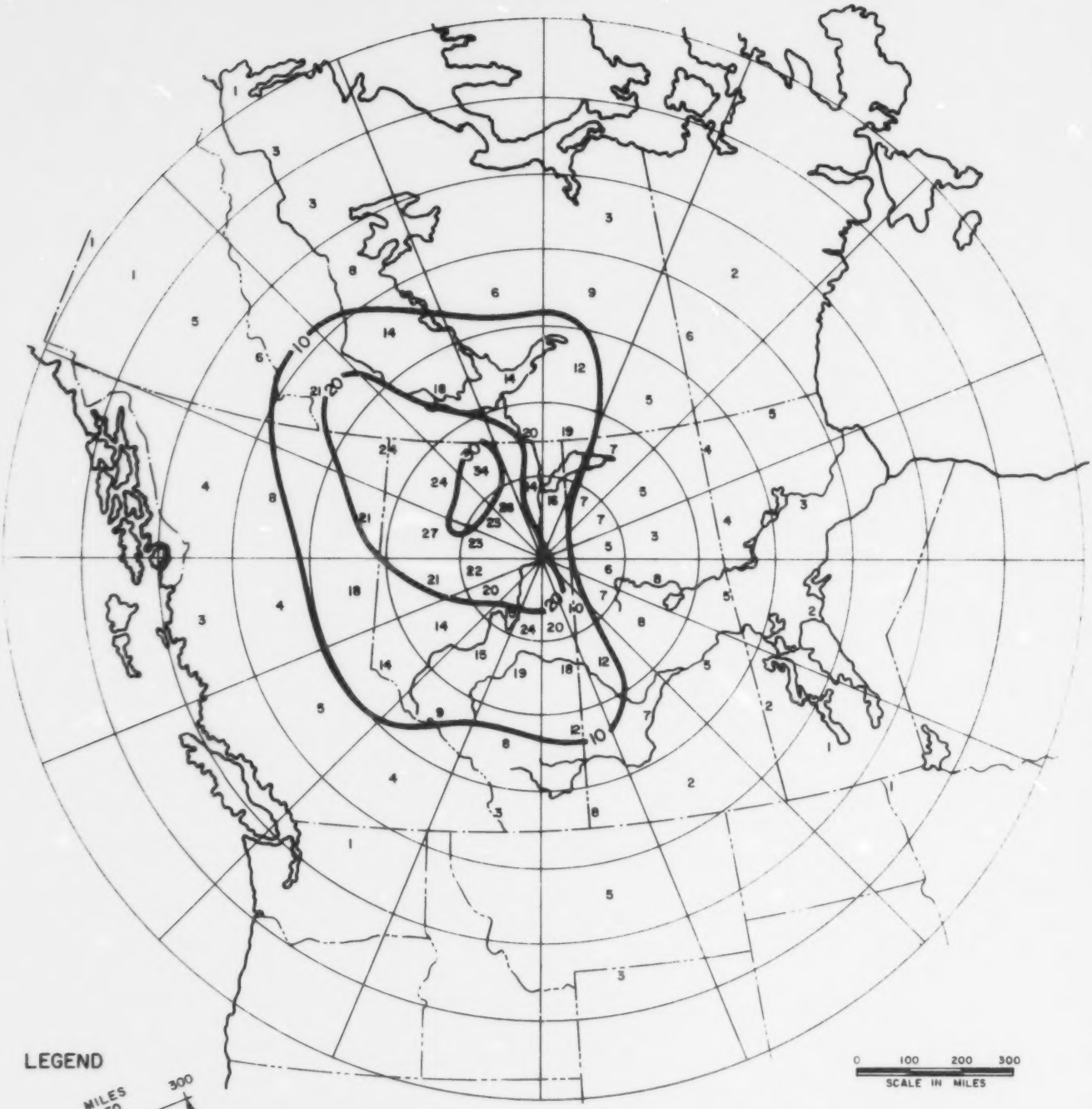
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

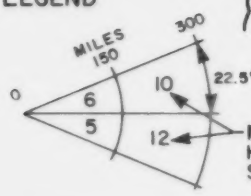
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 33



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – MODERATE

DIRECTION – IN TO STUDY AREA

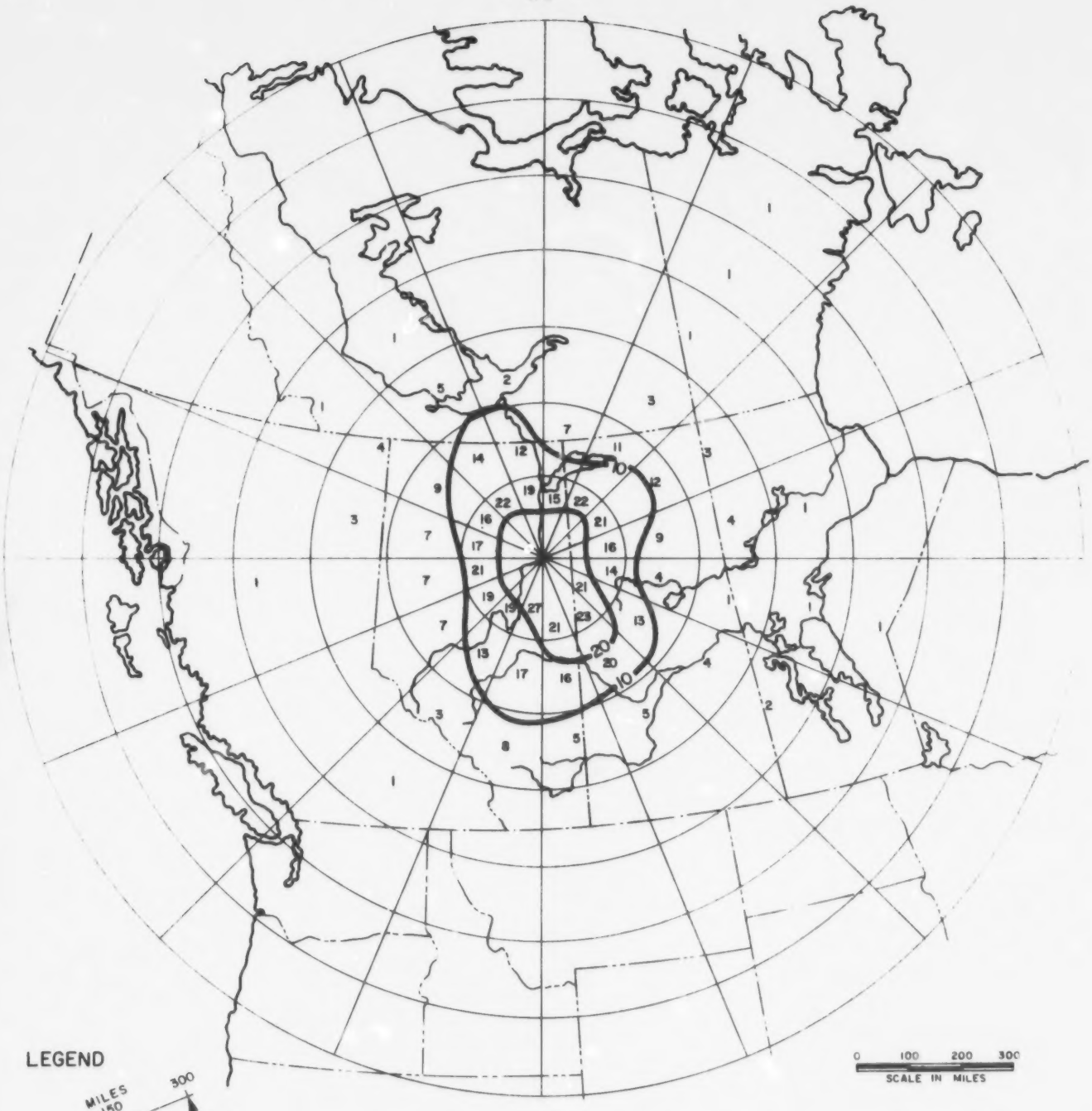
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 34



LEVEL – SURFACE

72 HOUR PRECIPITATION – MODERATE

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 35

LEVEL – 925 mb

72 HOUR PRECIPITATION – MODERATE

DIRECTION – OUT FROM STUDY AREA

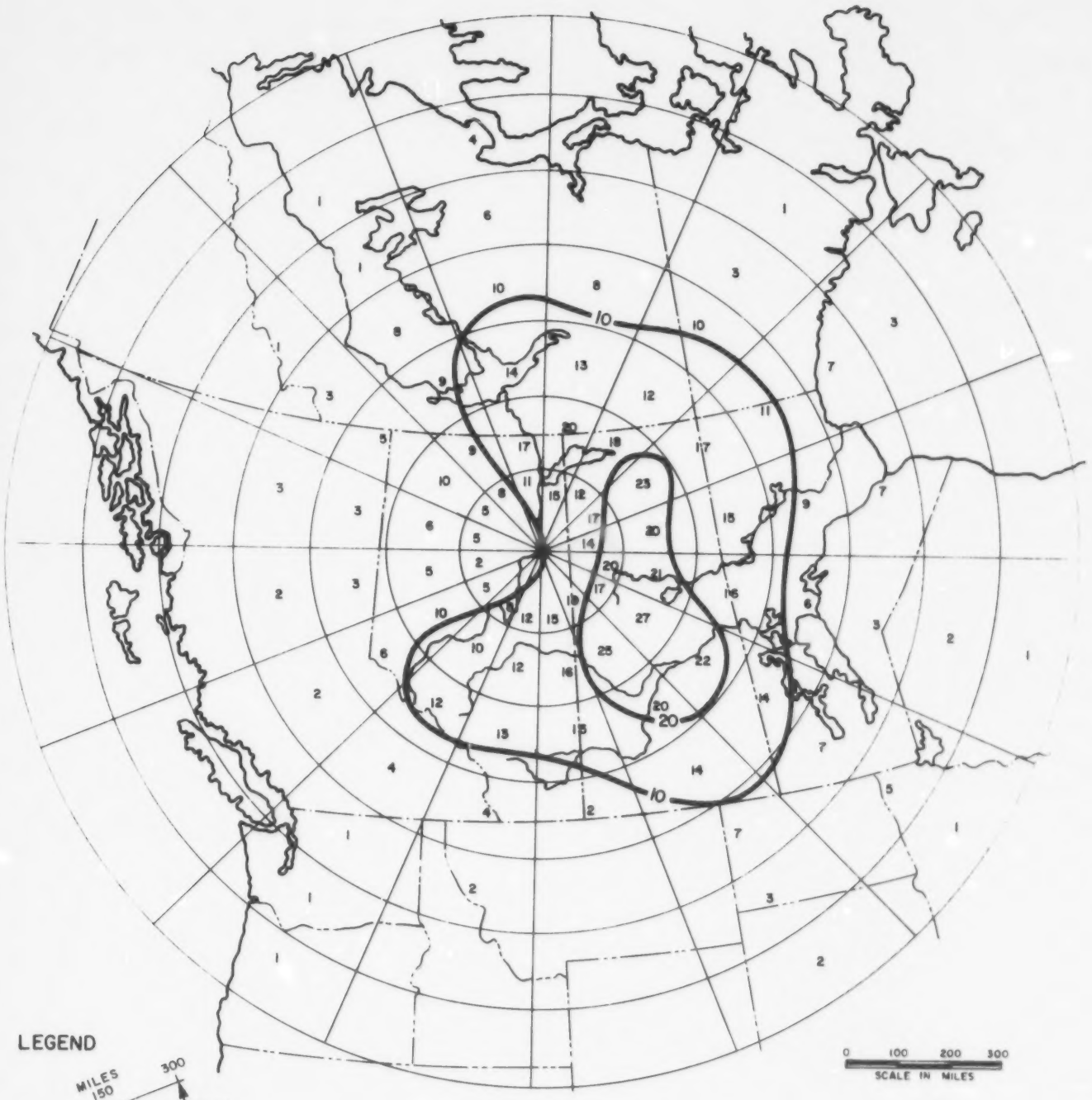
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

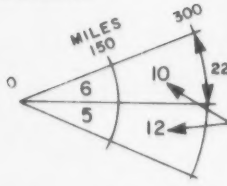
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 36



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – MODERATE

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

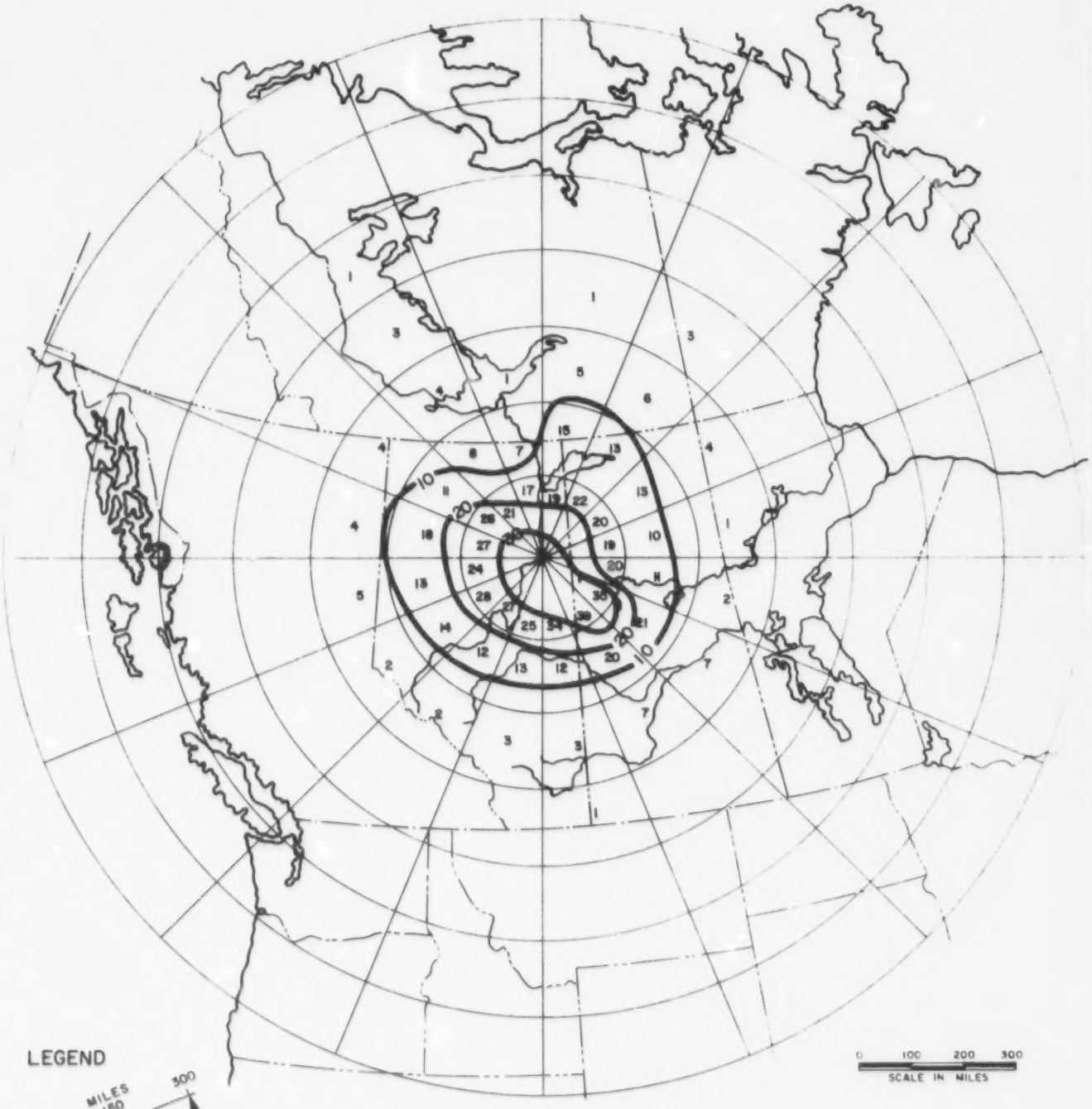
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

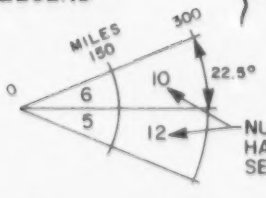
FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 37

HEAVY PRECIPITATION
Surface - 925 mb - 830 mb Levels
In To and Out From Study Area



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – HEAVY

DIRECTION – IN TO STUDY AREA

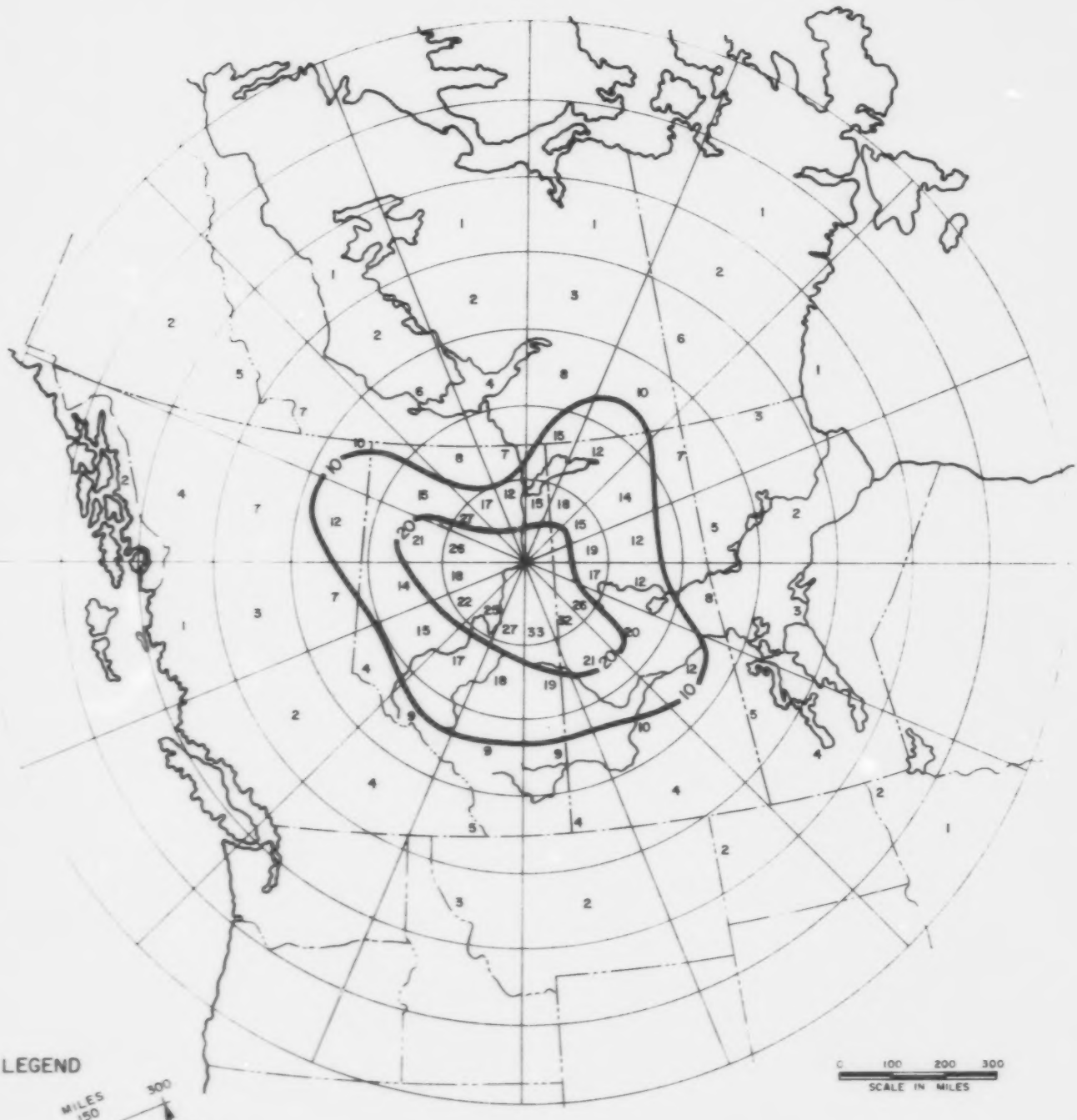
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

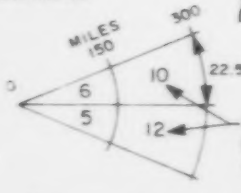
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 38



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL - 925 mb

72 HOUR PRECIPITATION - HEAVY

DIRECTION - IN TO STUDY AREA

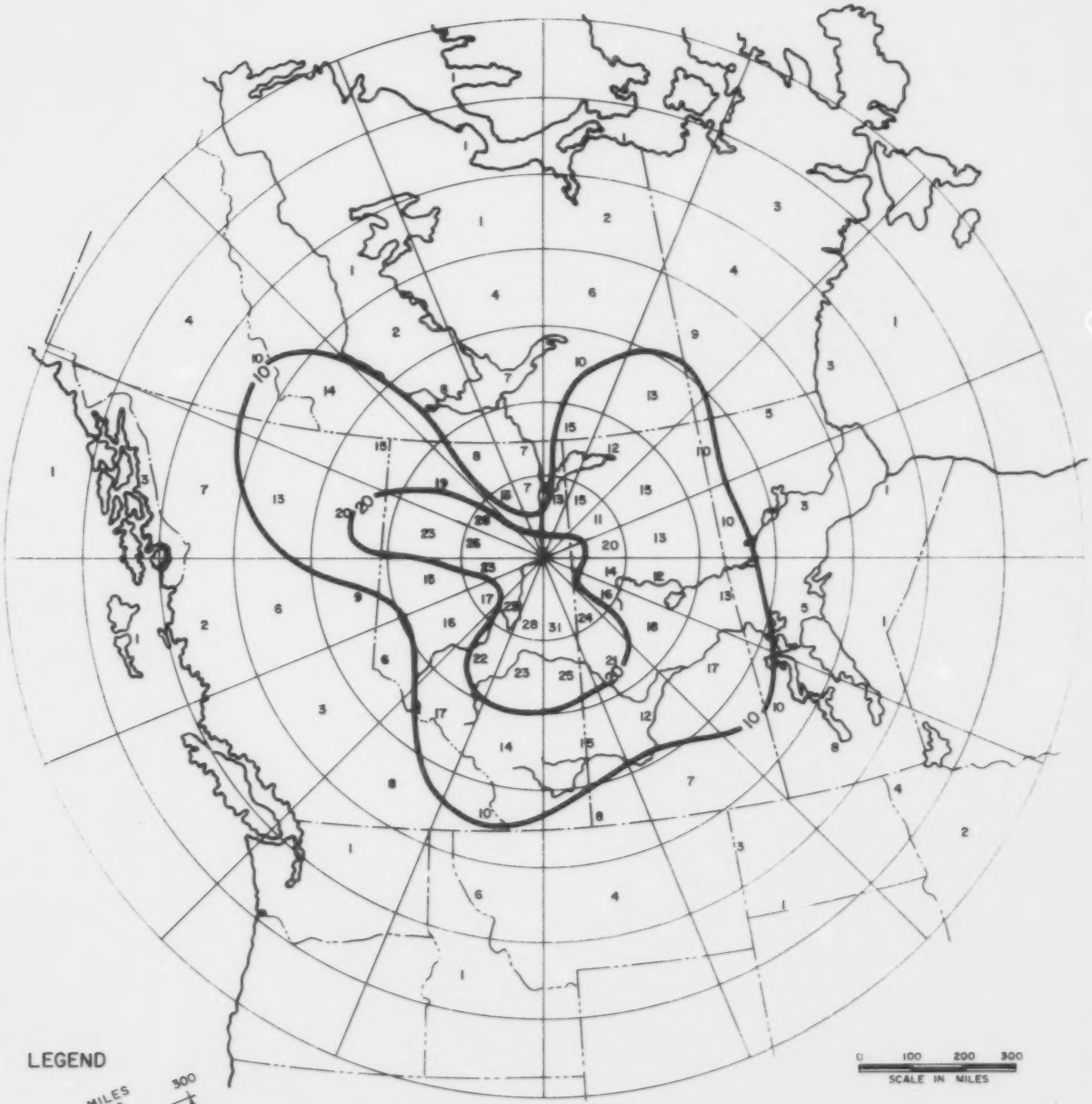
PERIOD - 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 39



LEVEL – 850 mb

72 HOUR PRECIPITATION – HEAVY

DIRECTION – IN TO STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

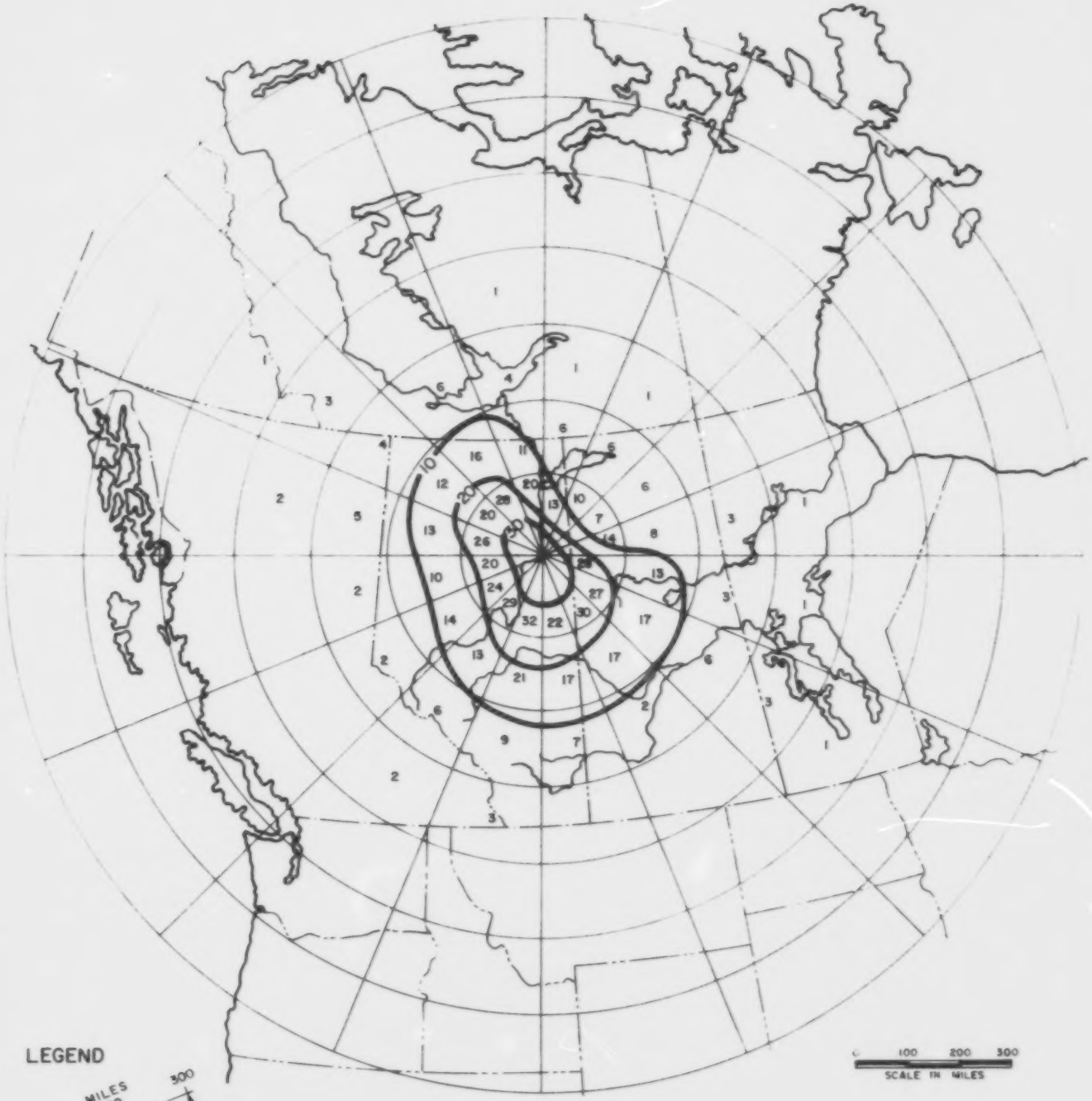
ACRES

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

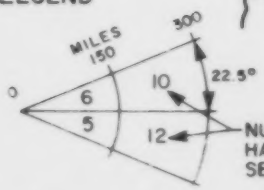
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 40



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – HEAVY

DIRECTION – OUT FROM STUDY AREA

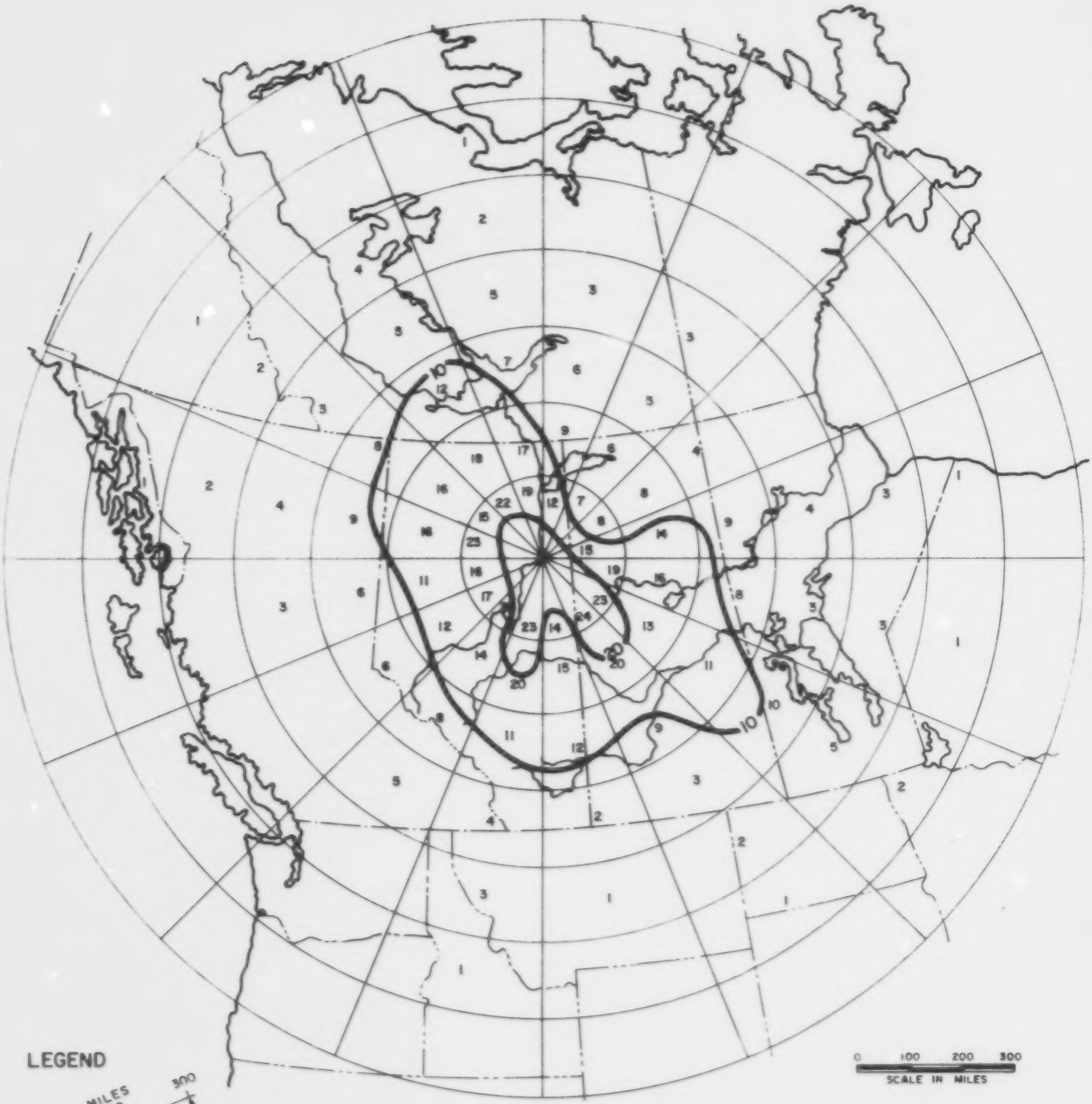
PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 41



LEVEL – 925 mb

72 HOUR PRECIPITATION – HEAVY

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

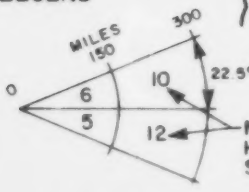
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 42

LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – HEAVY

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 AND 75 ANNUAL TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 43

5.4 - Four-Year Total Seasonal Frequencies

Because of the relatively limited number of occurrences of moderate and heavy precipitation conditions, seasonal frequencies were analyzed only for nil and light precipitation at the surface and 850-mb levels. These analyses are shown on Figures 44 to 75. Seasons were defined as December-January-February (winter), March-April-May (spring), June-July-August (summer) and September-October-November (fall).

In the case of nil precipitation, for air parcels moving in to the study area, the dominant surface level frequencies are from the west-southwest in winter and fall, the west in spring and the west-northwest in summer. A secondary bias from the south-southeast shows in the spring. At the 850-mb level dominant frequencies are from the northwest in winter, west in spring, northwest in summer and west-northwest in fall.

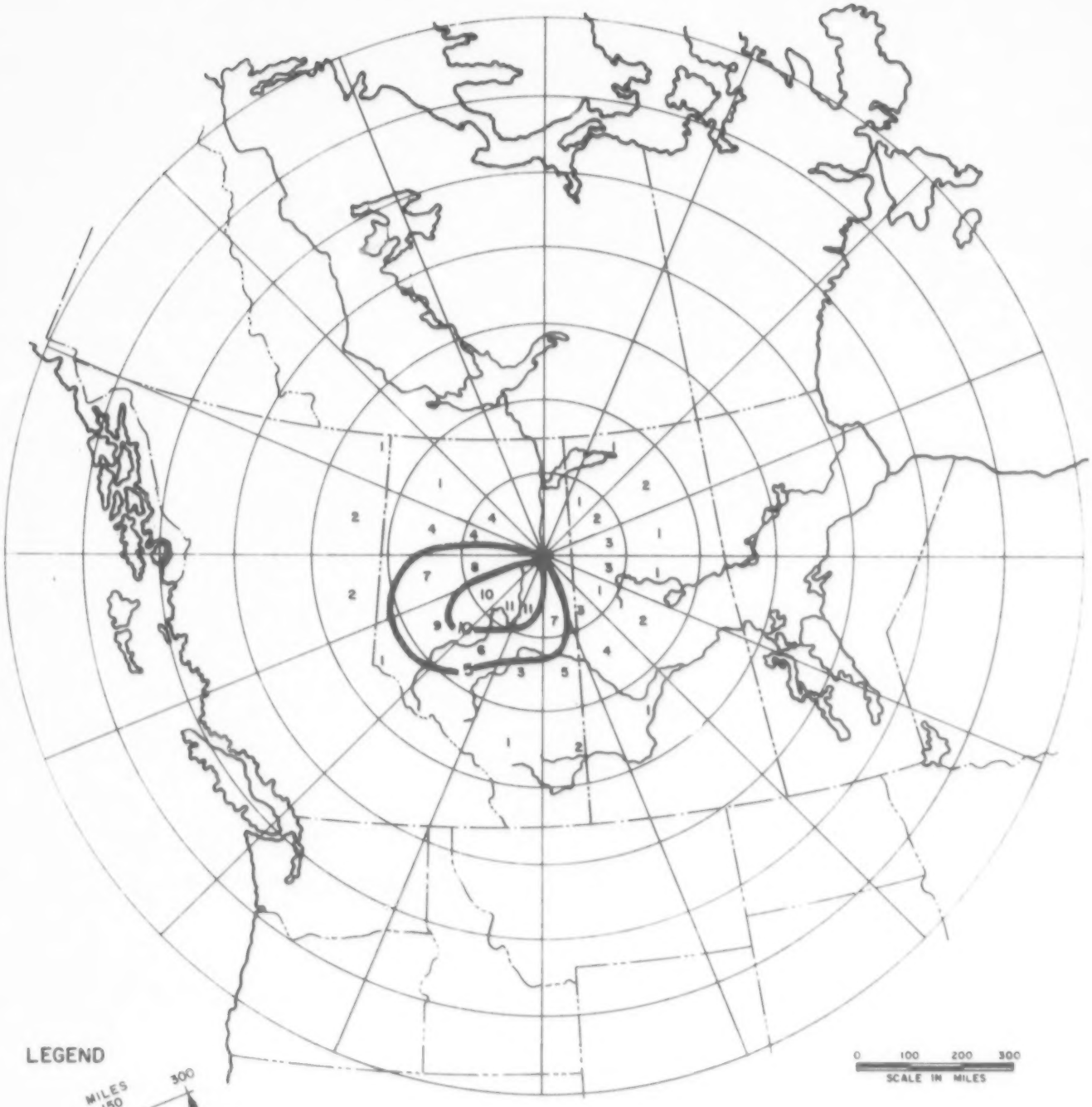
For air parcels moving out from the study area, under nil precipitation conditions, the dominant surface level frequencies are to the northeast in winter and spring and east-northeast in summer and fall. A secondary bias to the north-northwest shows in the spring. At 850 mb the dominant frequencies are to the east-southeast in winter and fall and east-northeast in spring and summer.

In the case of light precipitation and air parcels moving in to the study area at the surface level, winter frequencies slightly favor the westerly directions, are dominant from the east-southeast in the spring, the northwest in the summer and the southwest in the fall. At 850 mb the dominant frequencies are from the northwest in winter, west in the spring, northwest in the summer and west in the fall.

In the case of light precipitation and air parcels moving out from the study area, dominant frequencies at the surface level are to the east in winter and the northwest in spring; frequencies are dominant to the east again in summer and fall. At the 850-mb level for these same conditions, dominant frequencies are to the east in all four seasons.

TOTAL SEASONAL FREQUENCIES

NIL PRECIPITATION
Surface - 850-mb Levels
In To Study Area



LEVEL - SURFACE

72 HOUR PRECIPITATION - NIL

DIRECTION - IN TO STUDY AREA

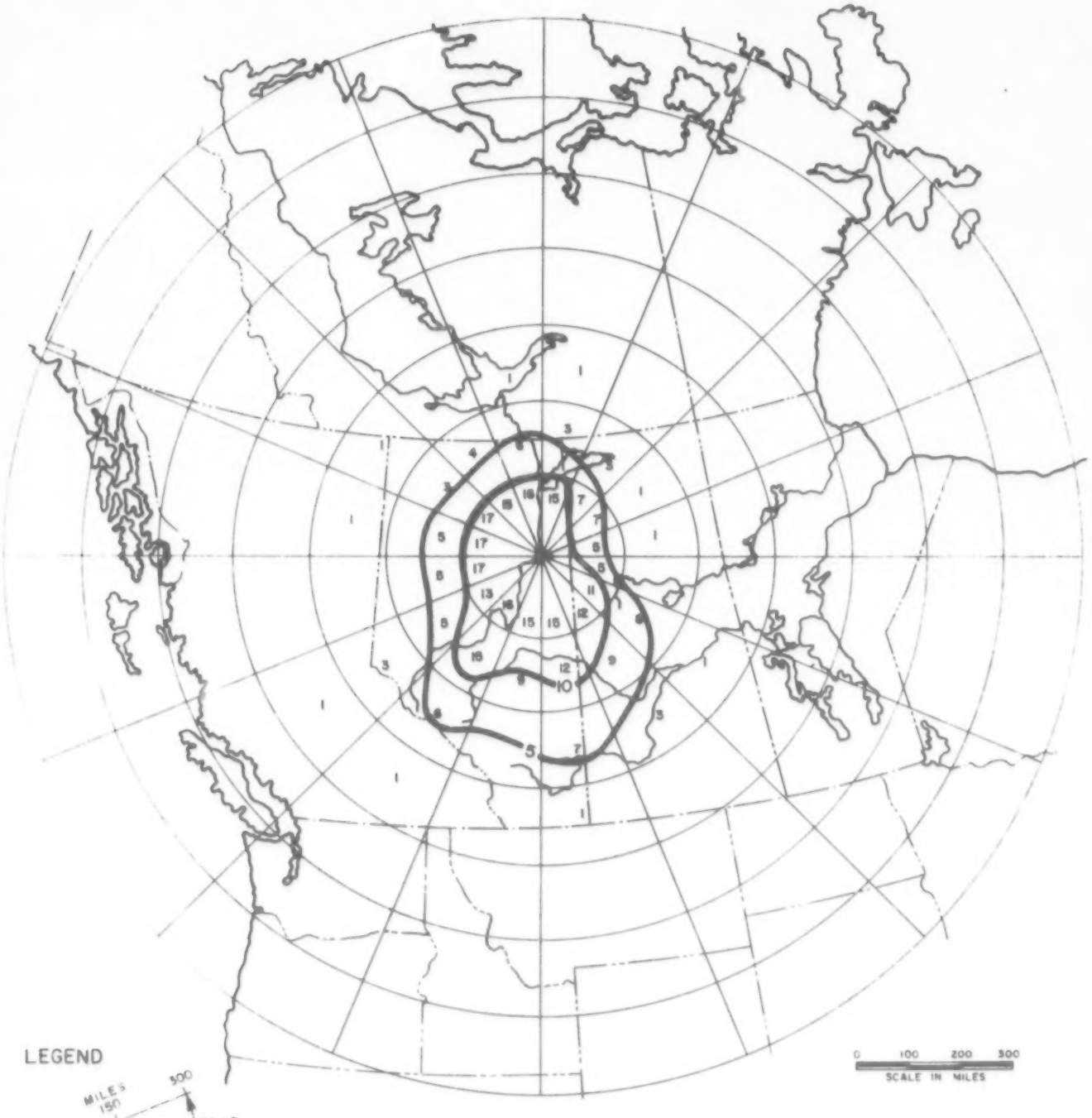
PERIOD - 1968, 73, 74 & 75, DEC., JAN., FEB., TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

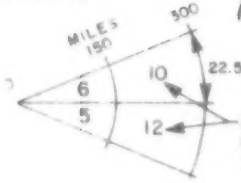
AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 44



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL - SURFACE

72 HOUR PRECIPITATION - NIL

DIRECTION - IN TO STUDY AREA

PERIOD - 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 45

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

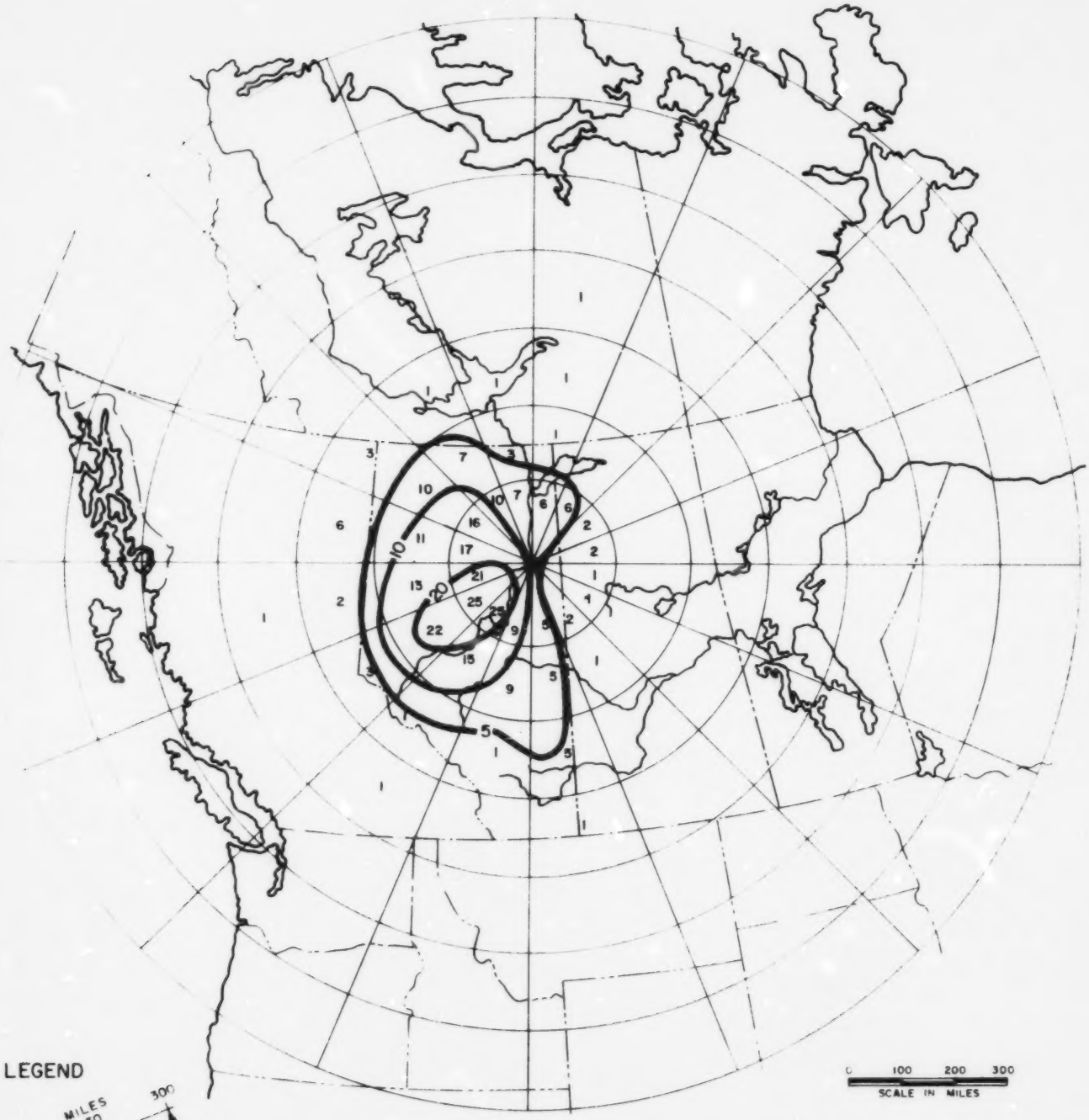
PERIOD – I '73, '74 & '75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 46



LEVEL - SURFACE

72 HOUR PRECIPITATION - NIL

DIRECTION - IN TO STUDY AREA

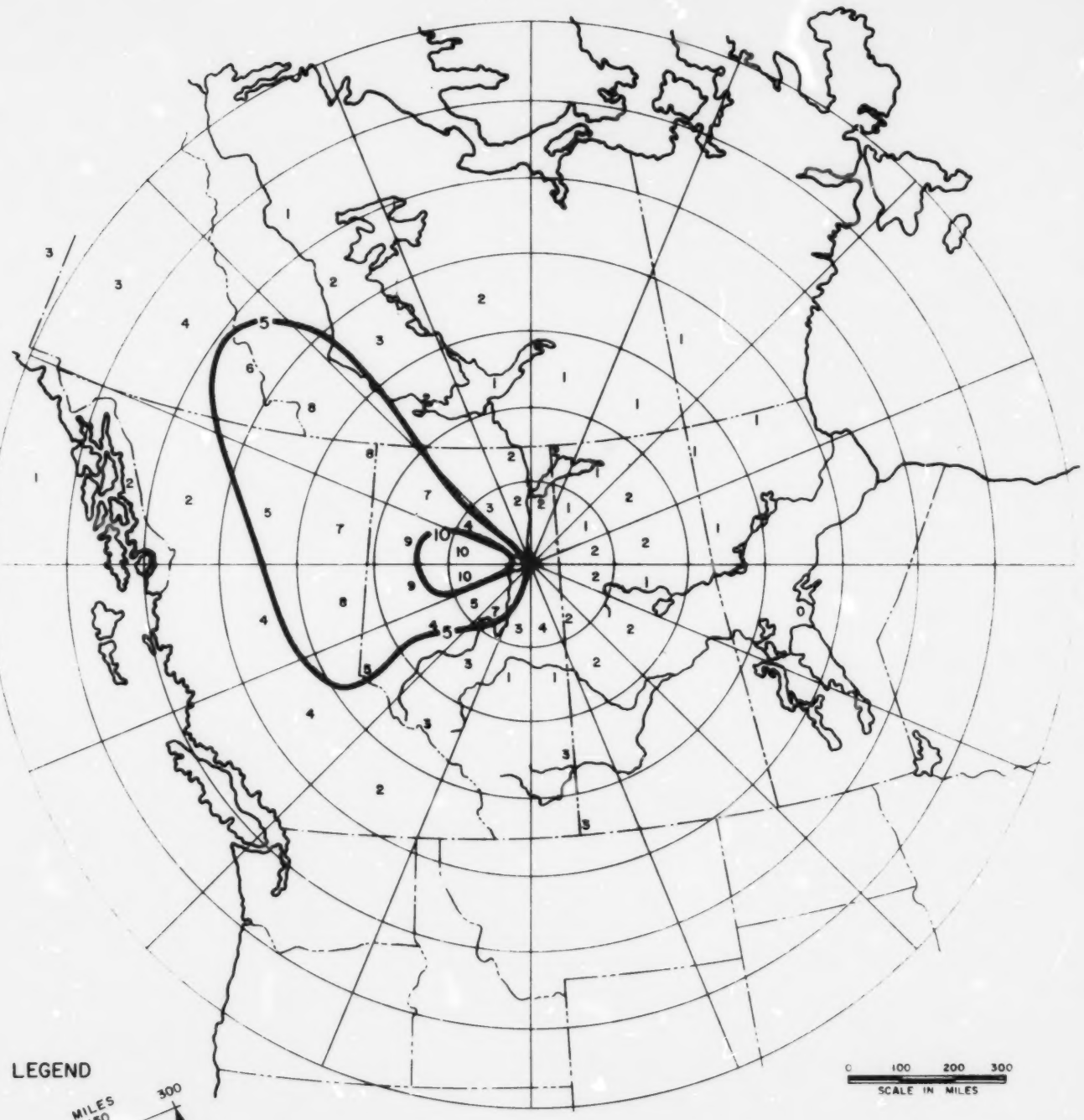
PERIOD - 1968, 73, 74 & 75, SEPT., OCT., NOV., TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 47



LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

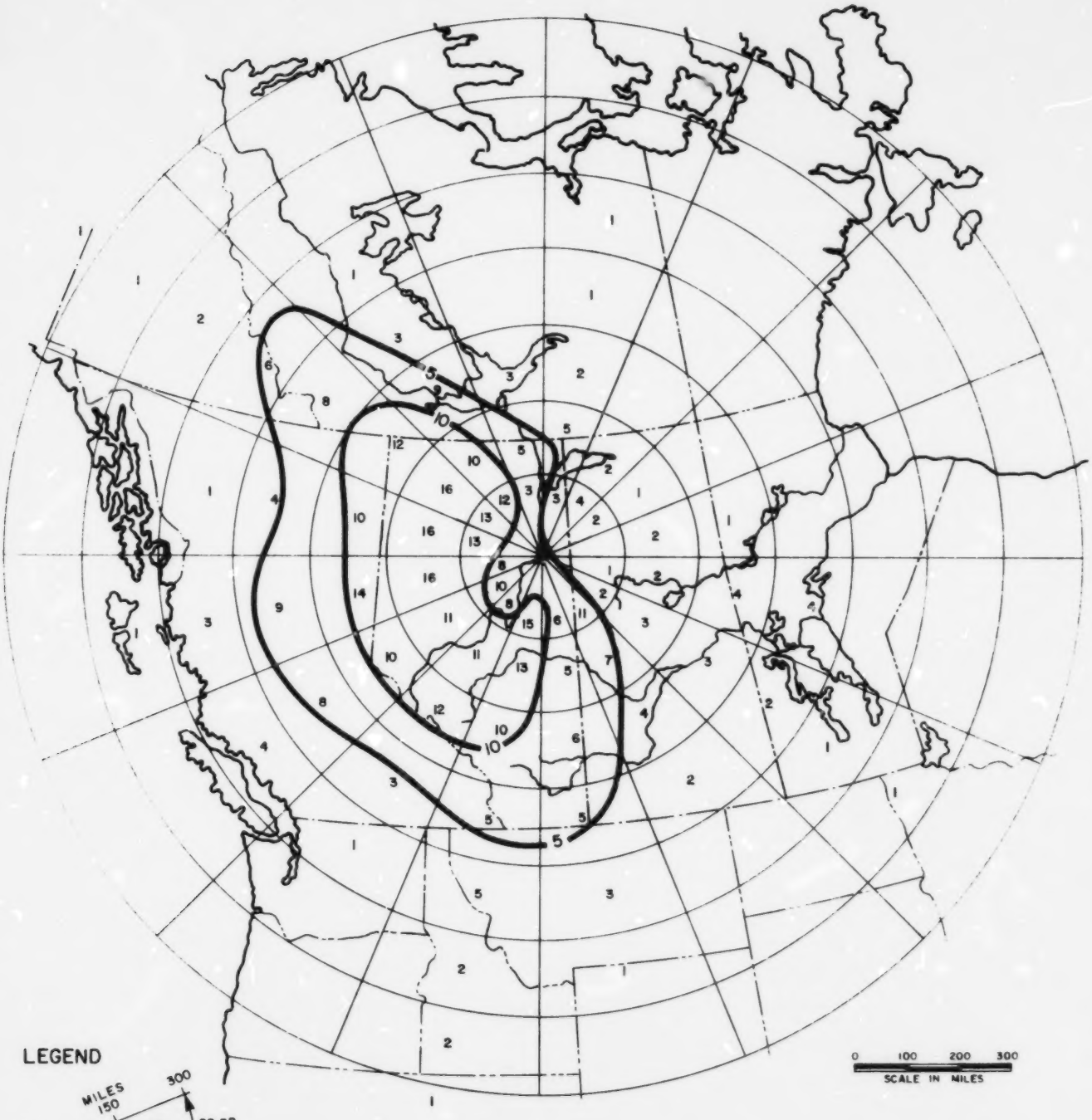
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 48



LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 49

LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

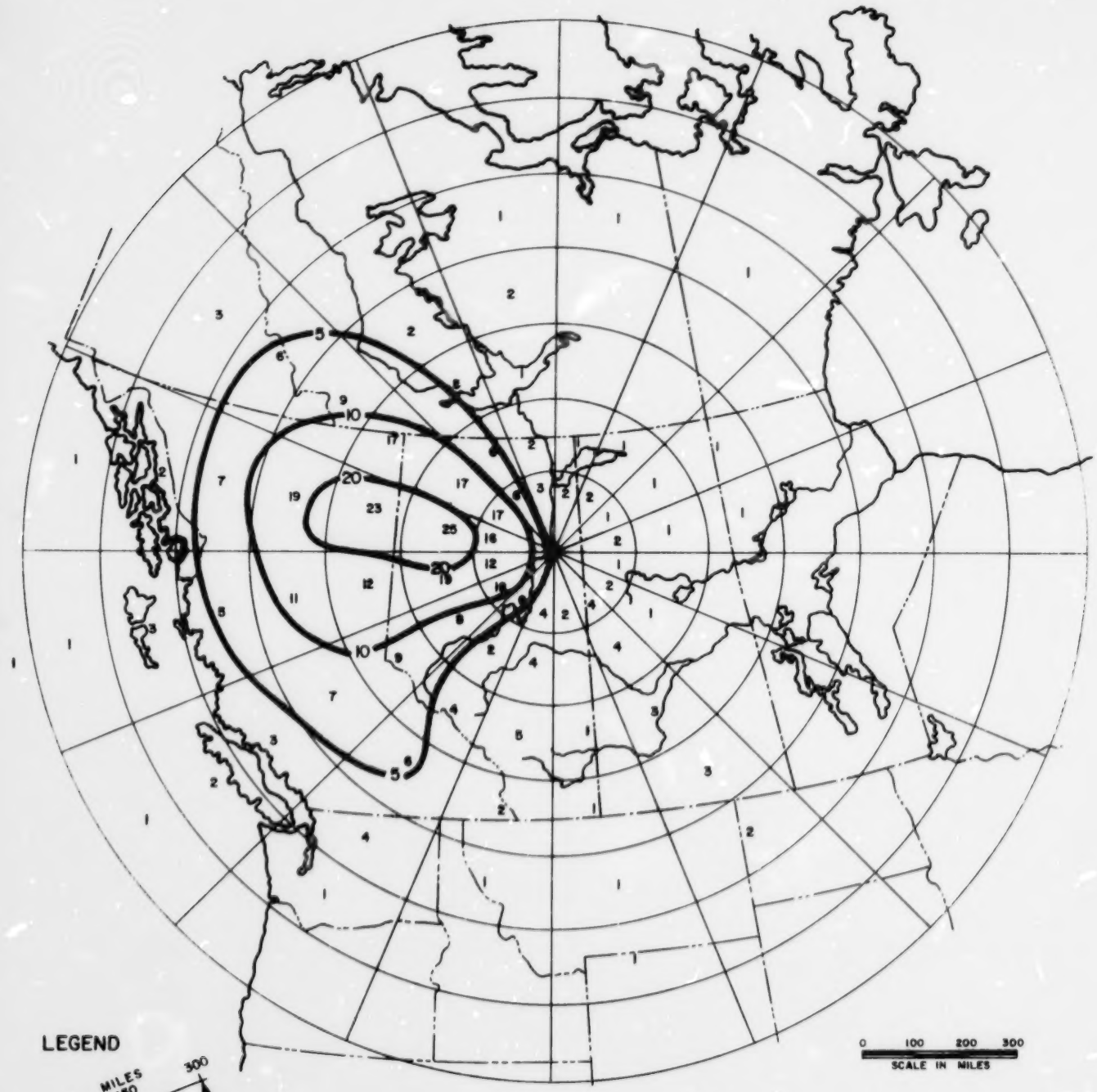
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

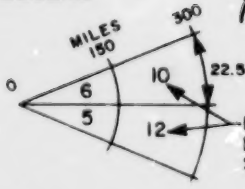
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 50



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – IN TO STUDY AREA

PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 51

NIL PRECIPITATION
Surface - 850-mb Levels
Out From Study Area

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB., TOTALS

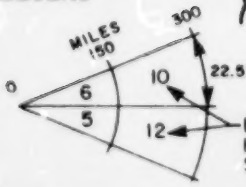
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 52

LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

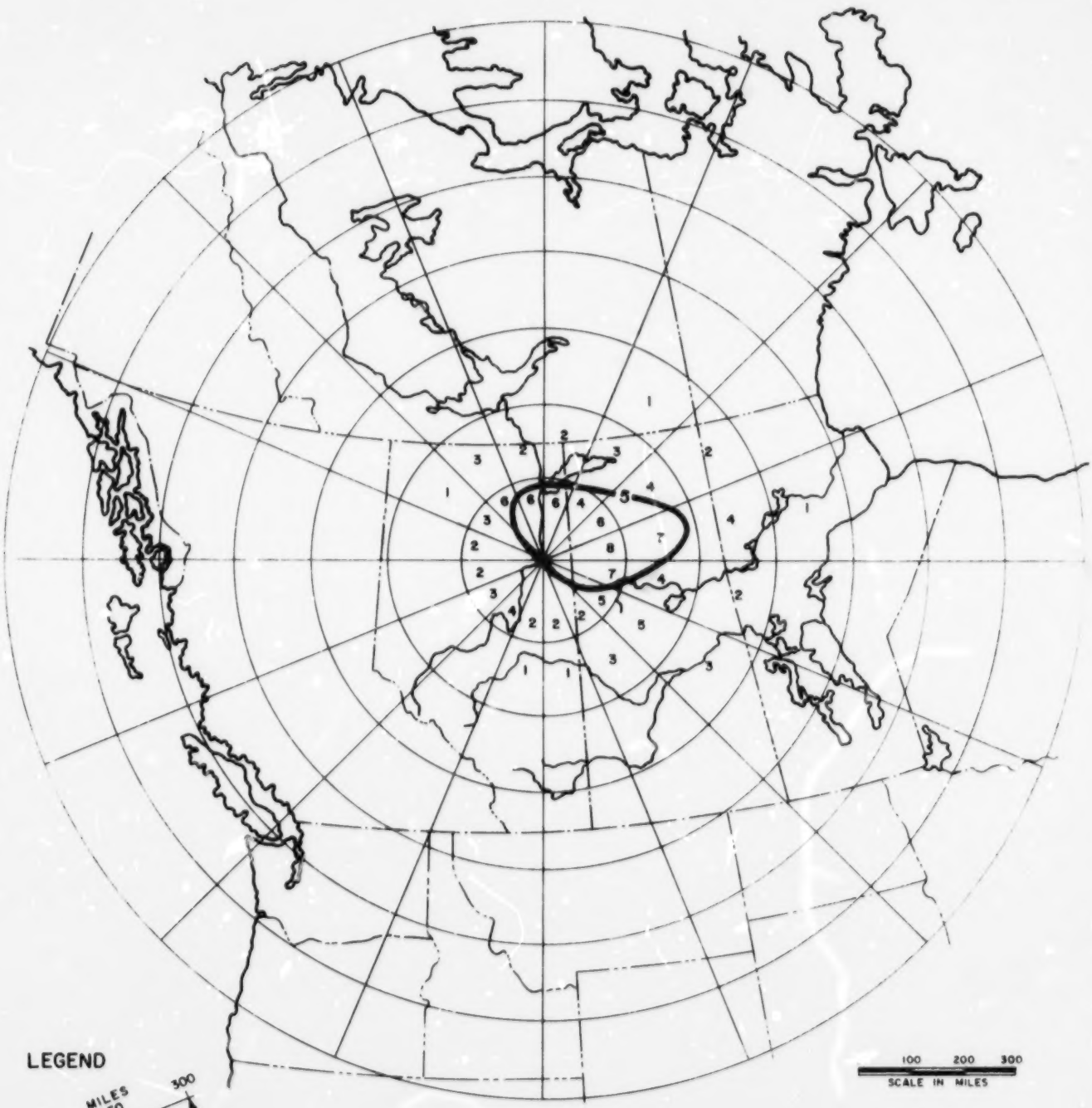
PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 53



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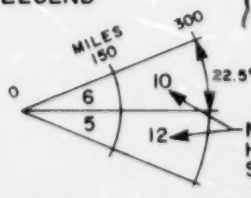


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 54

LEVEL – SURFACE

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 55

LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

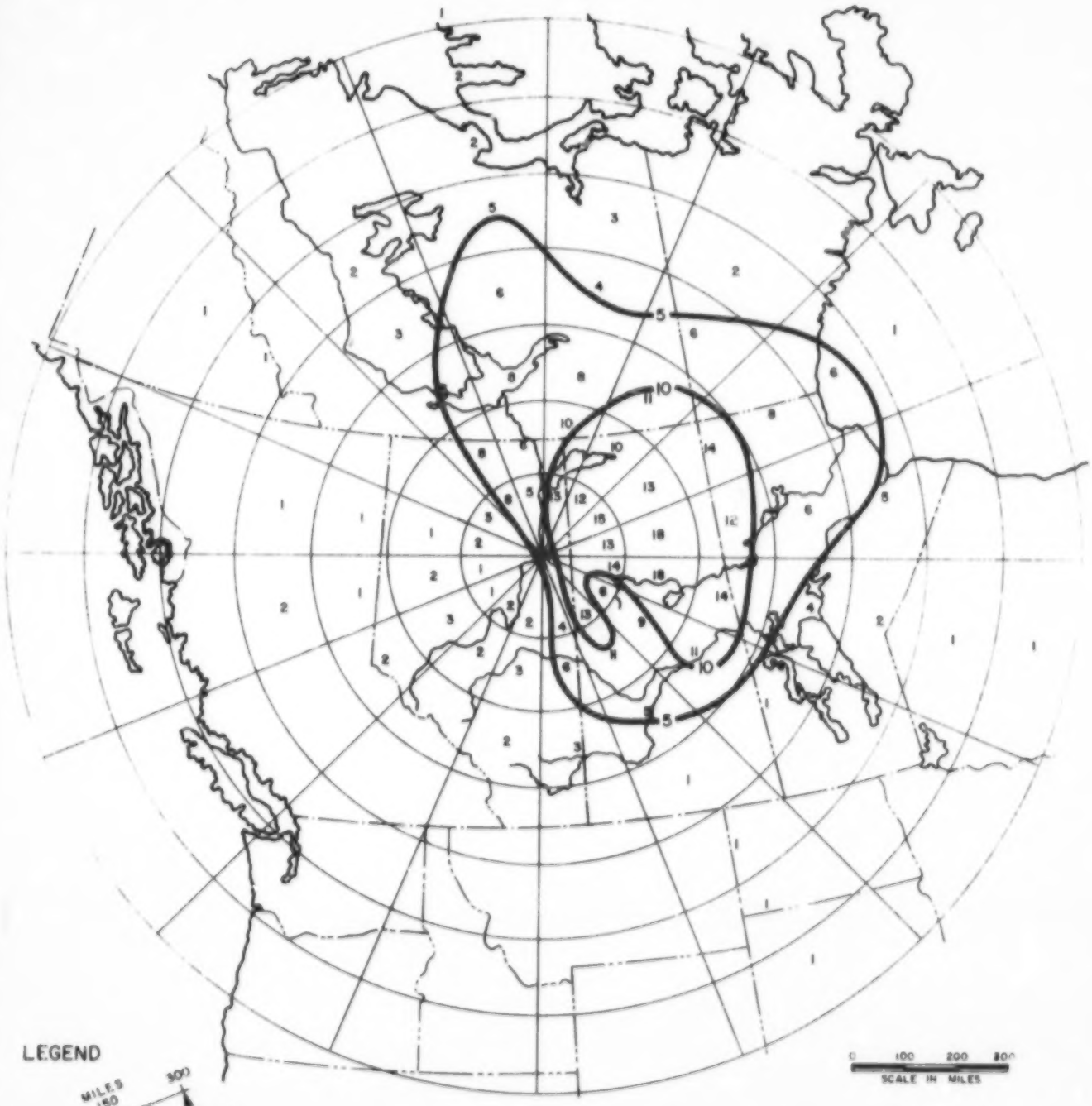
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 56



LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

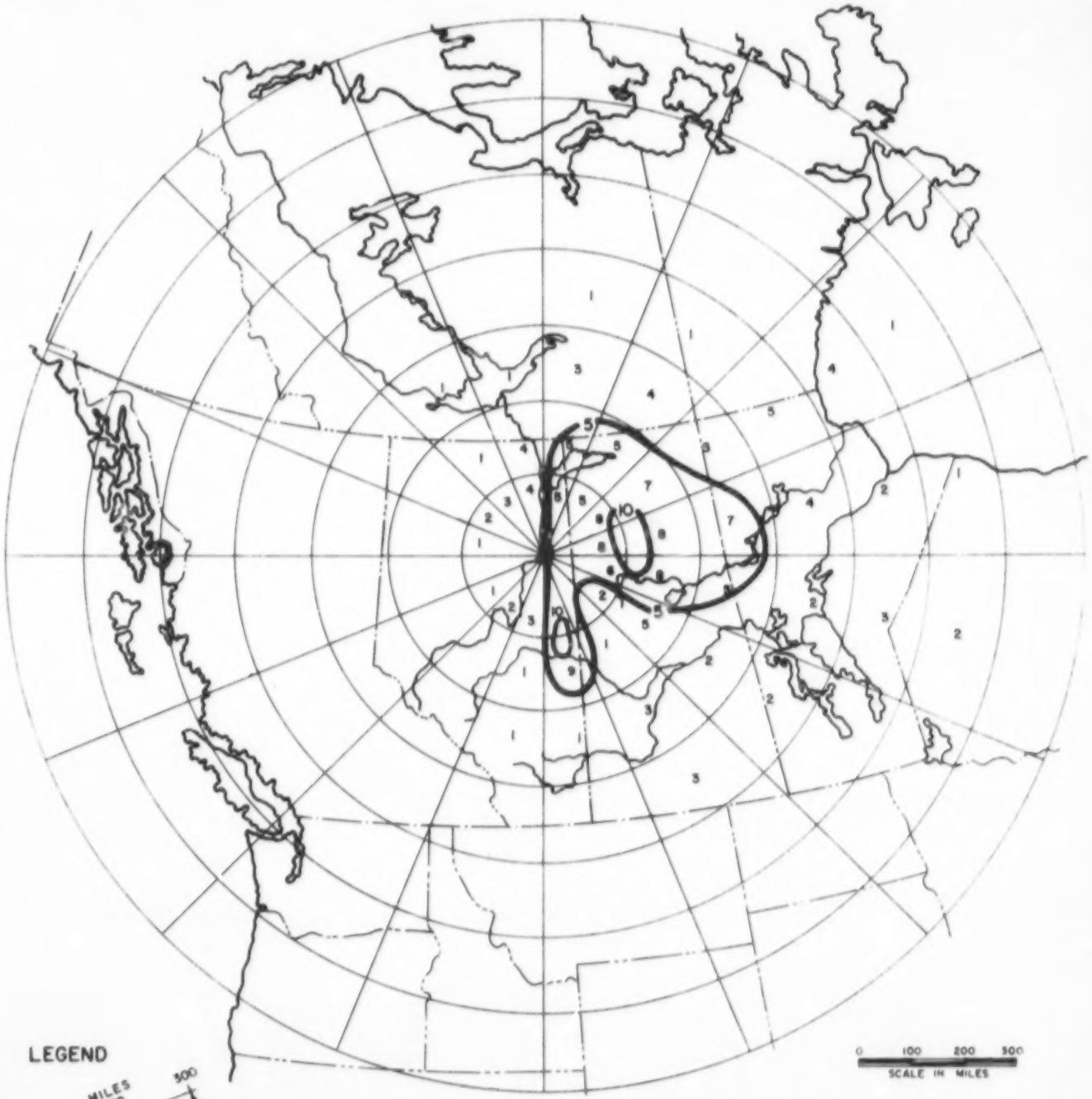
PERIOD - 1968, 73, 74, 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP - 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 57



LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

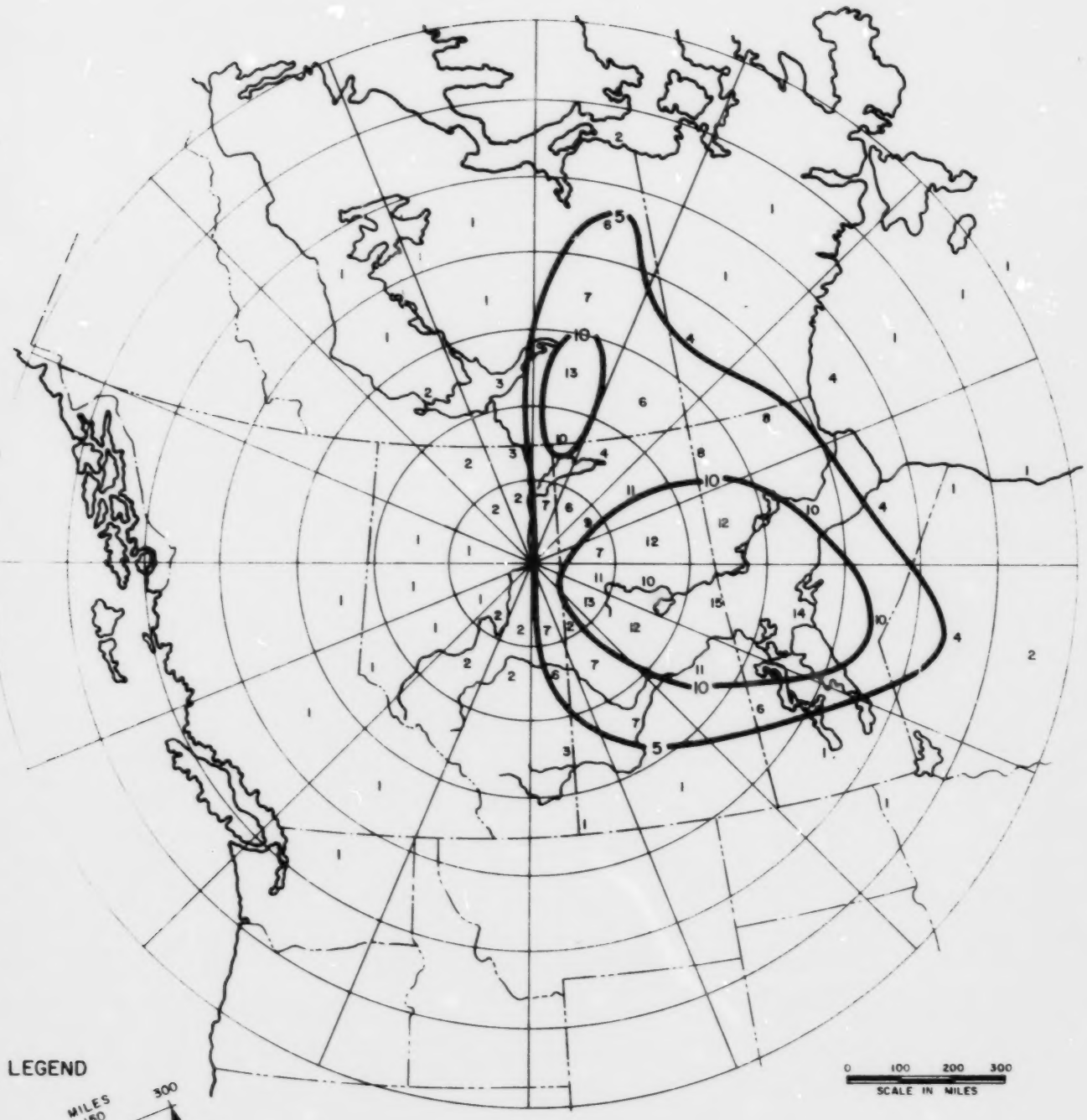
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

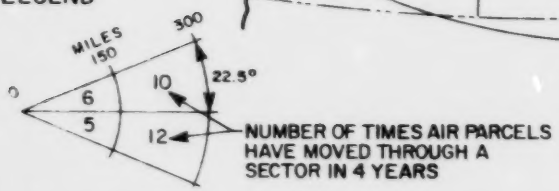
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 58



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – NIL

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74, 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

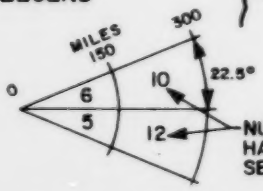
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 59

LIGHT PRECIPITATION
Surface - 850-mb Levels
In To Study Area

LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

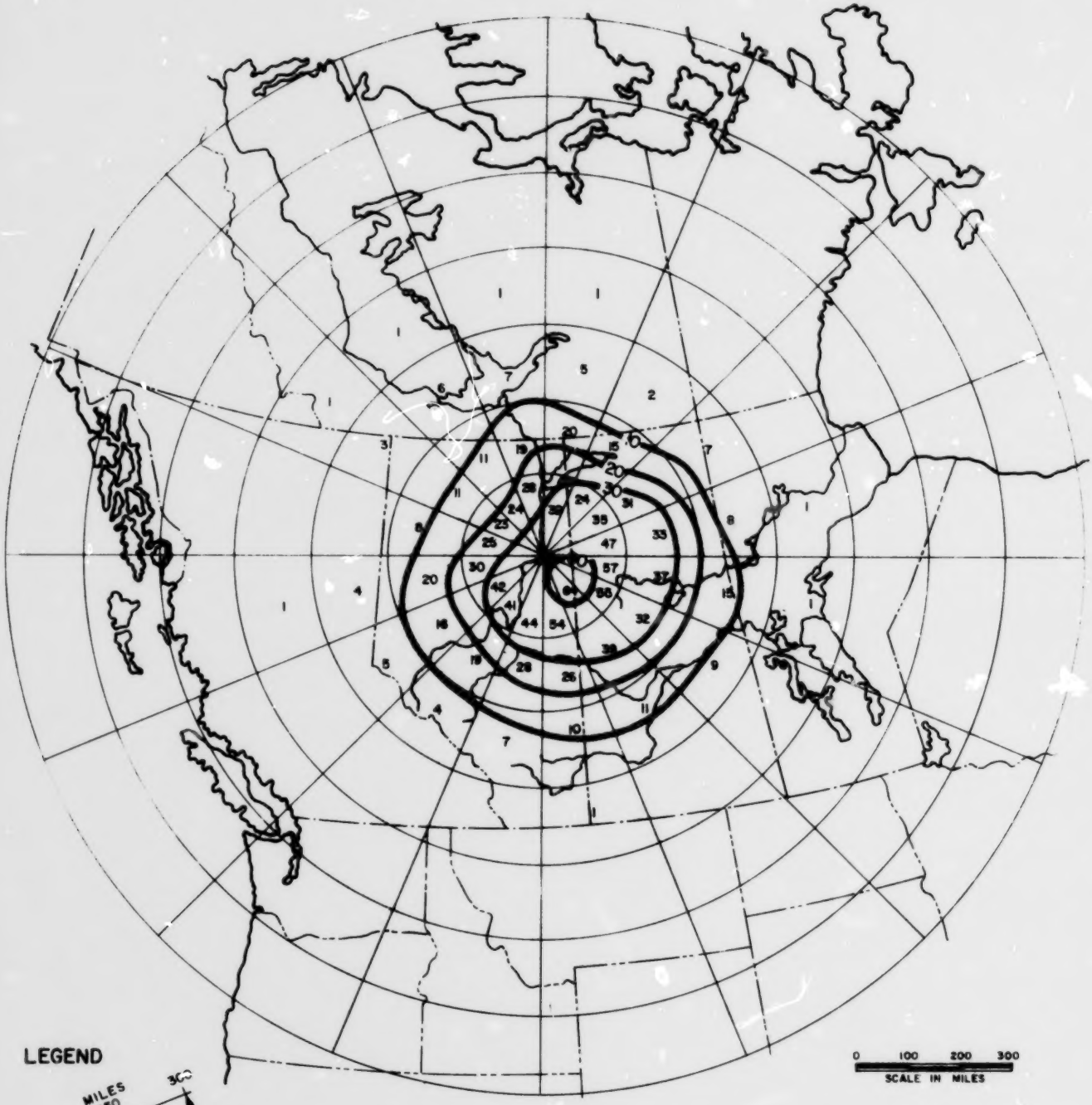
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 60



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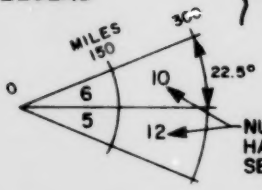


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

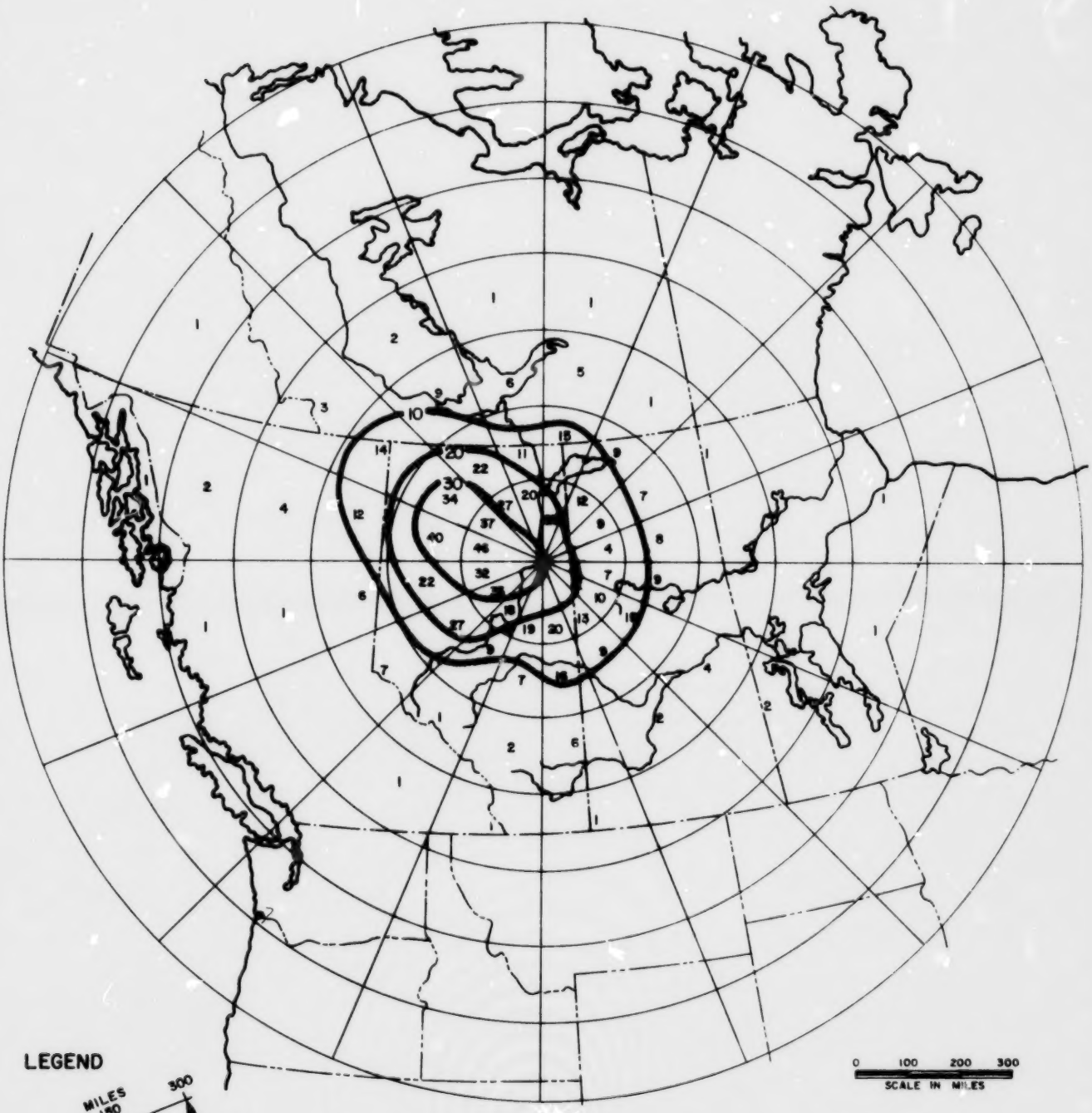
PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTAL

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 61



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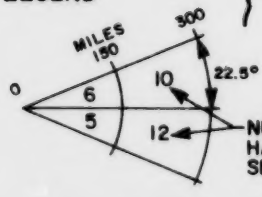


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

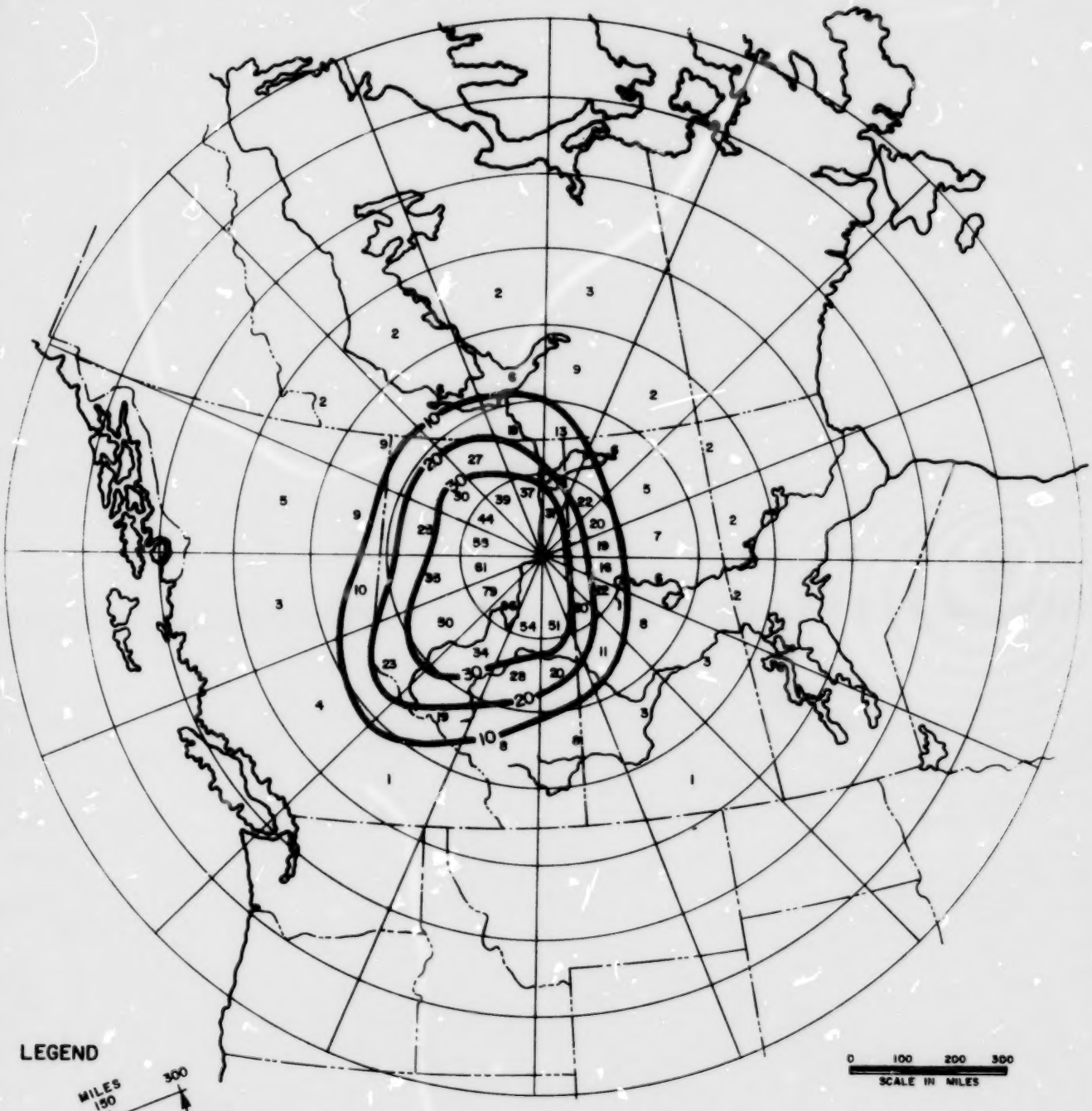
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 62



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

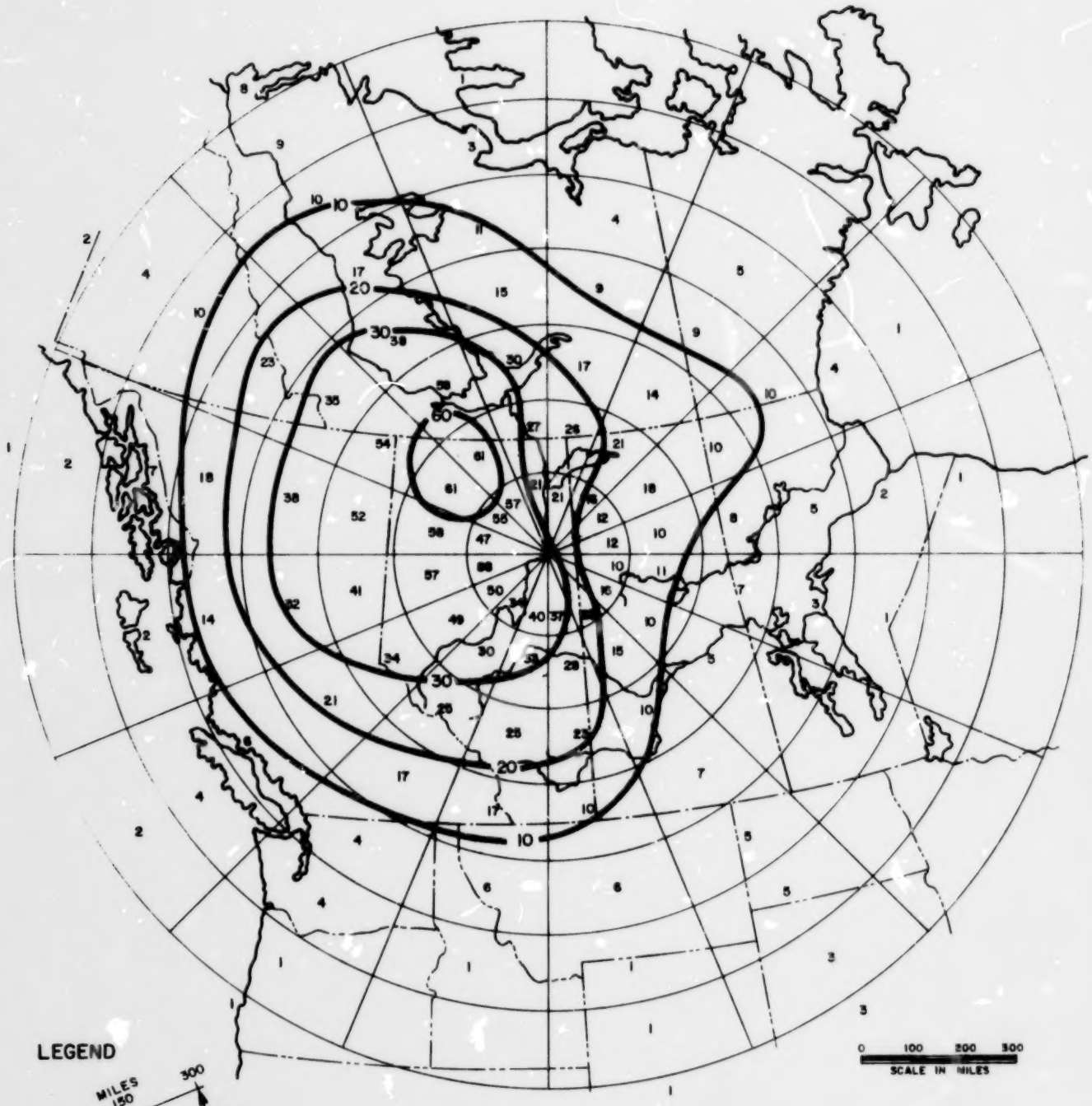
PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 63



LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

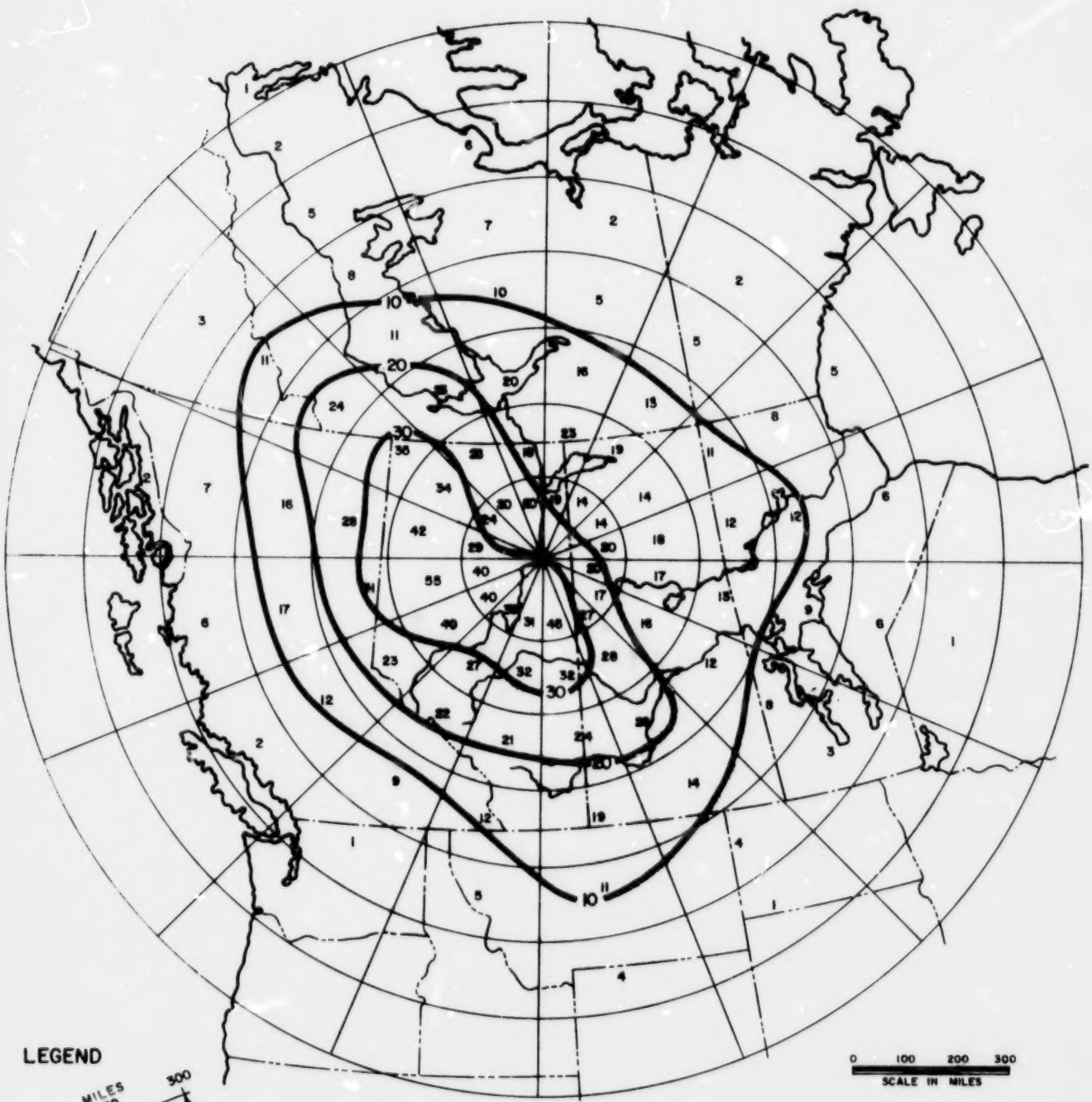
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

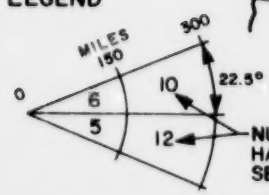
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 64



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

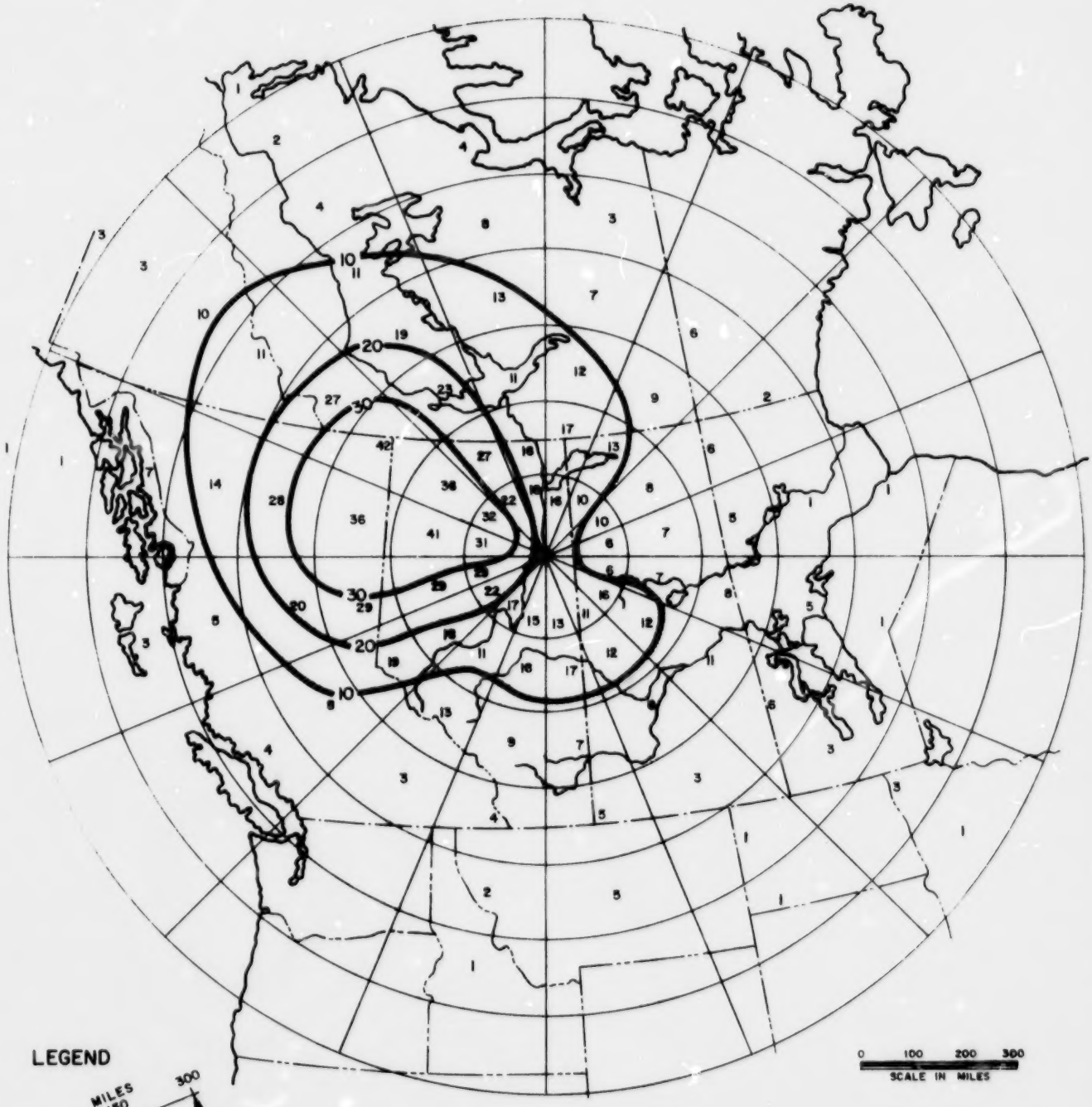
PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 65



LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

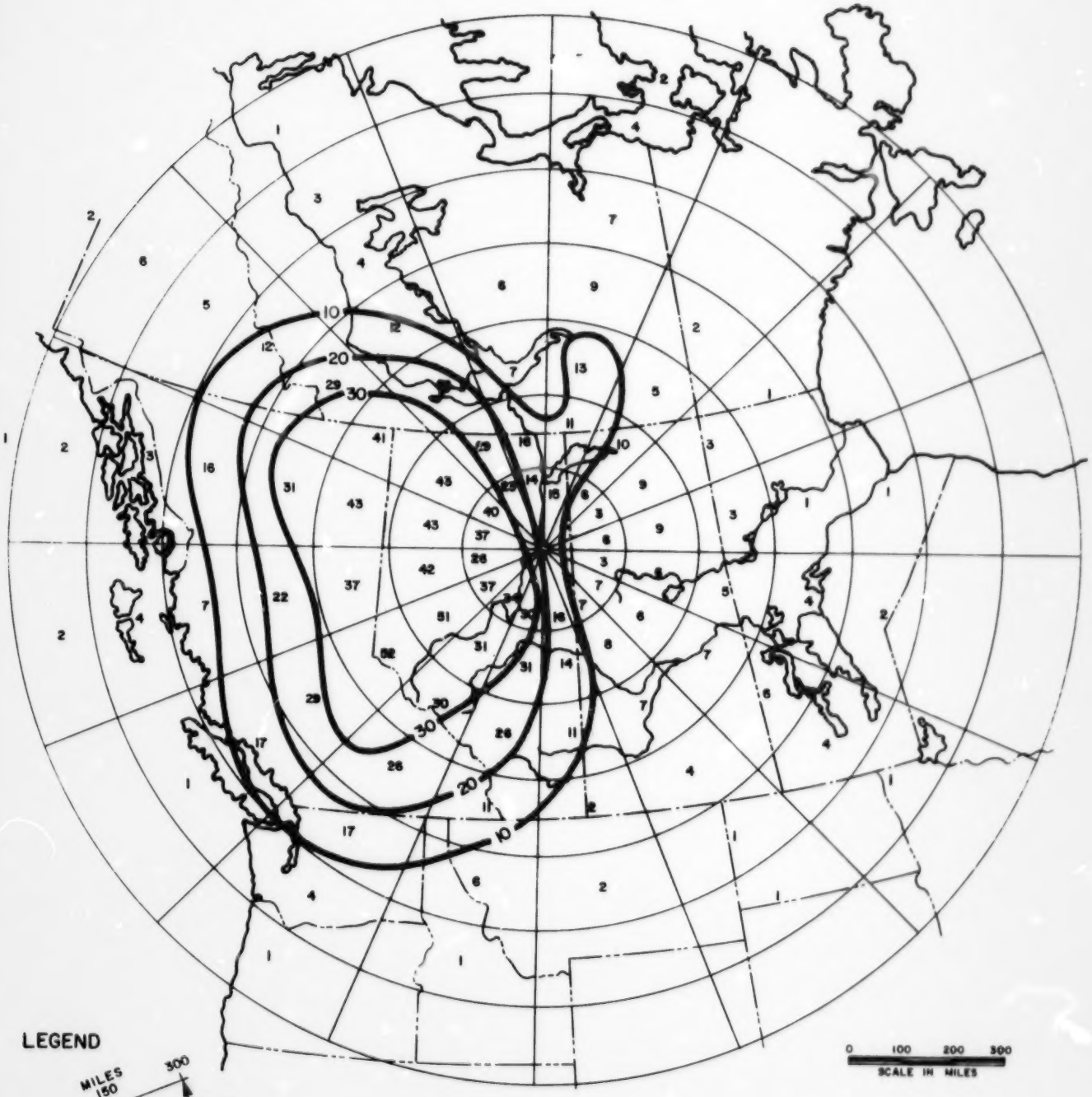
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 66



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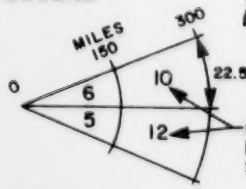


NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – IN TO STUDY AREA

PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

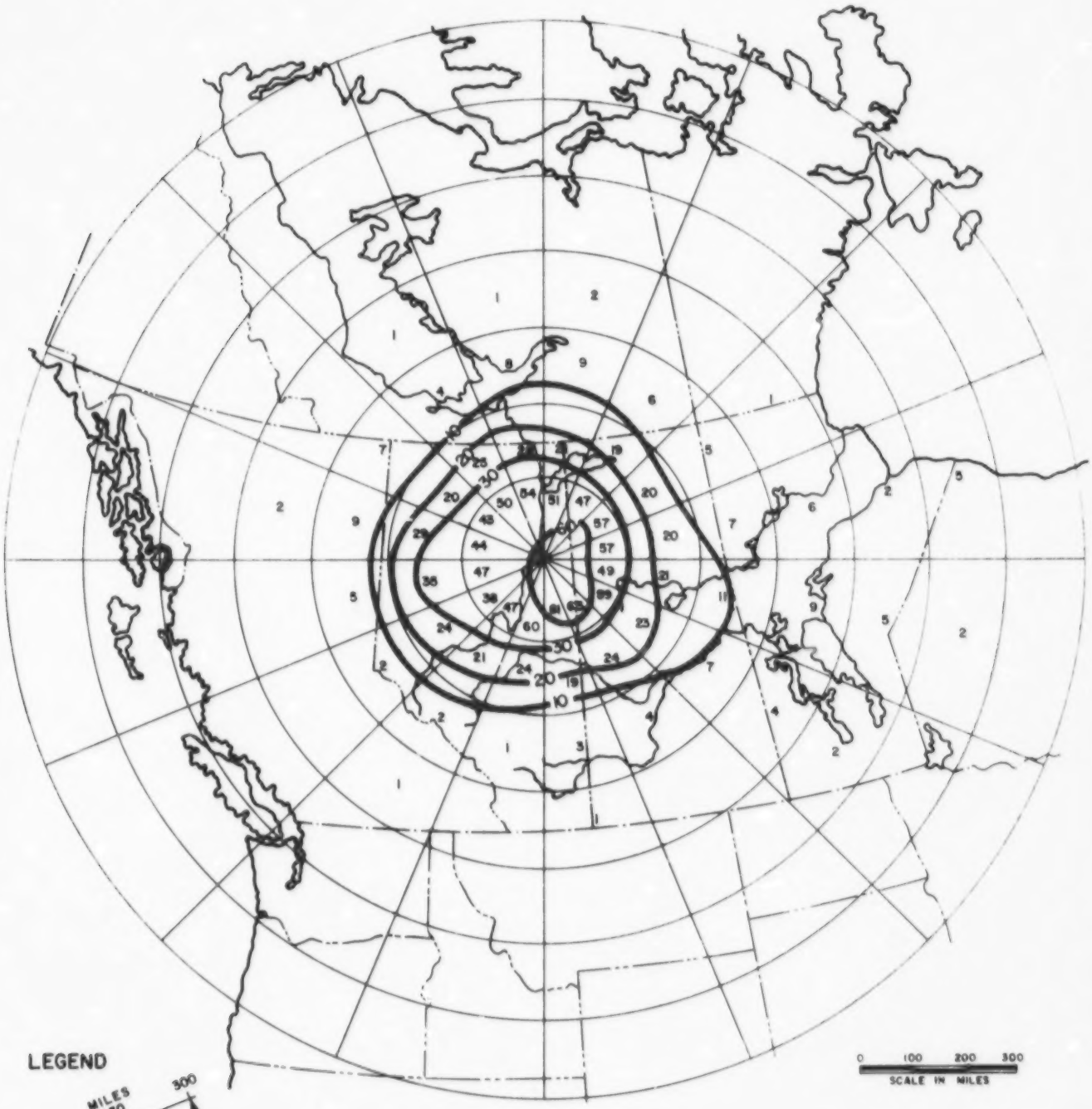
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 67

LIGHT PRECIPITATION
Surface - 850-mb Levels
Out From Study Area



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

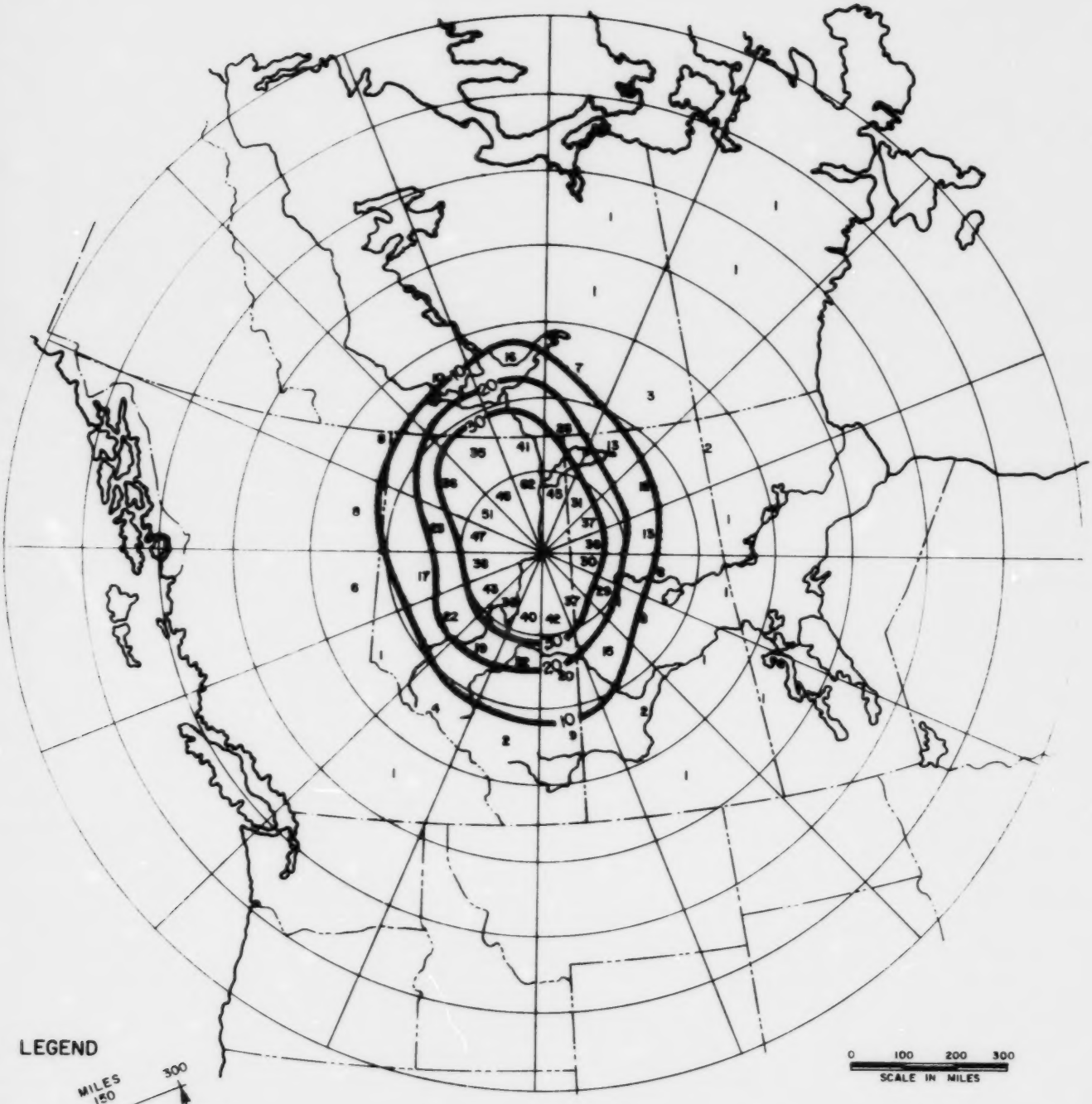
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 68



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

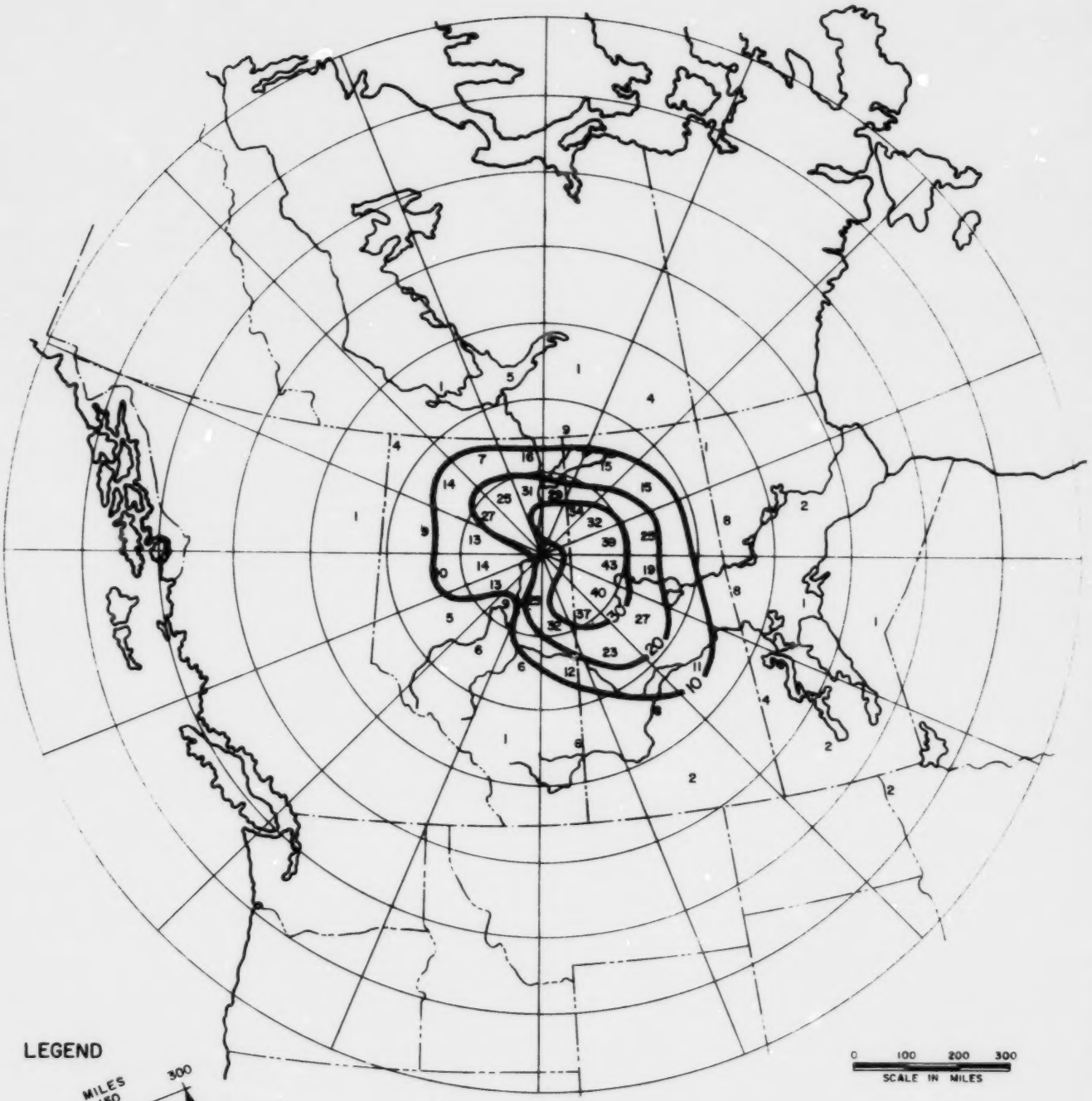
PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 69



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

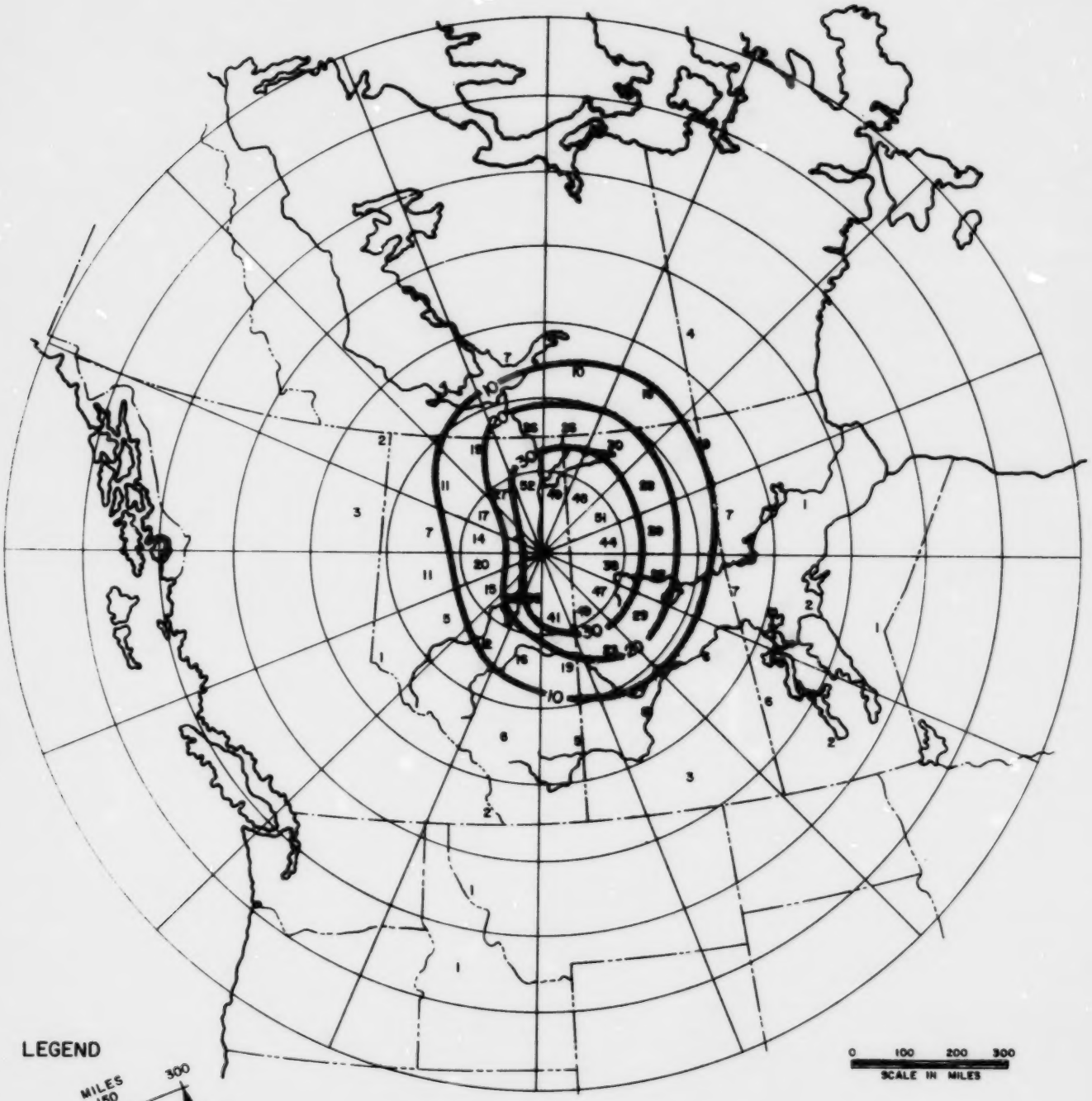
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 70



LEVEL – SURFACE

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

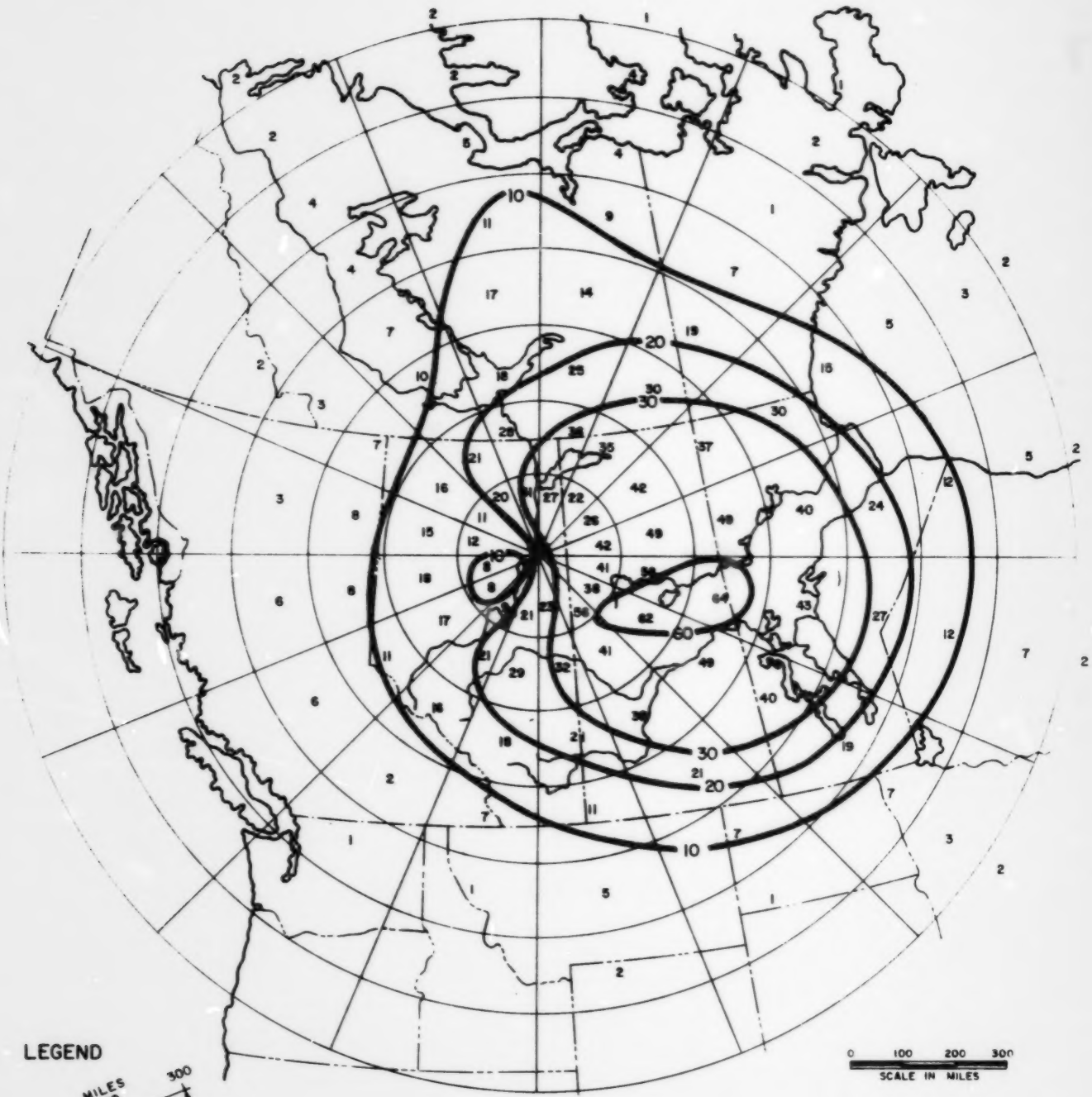
PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

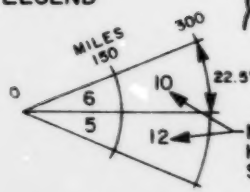
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 71



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

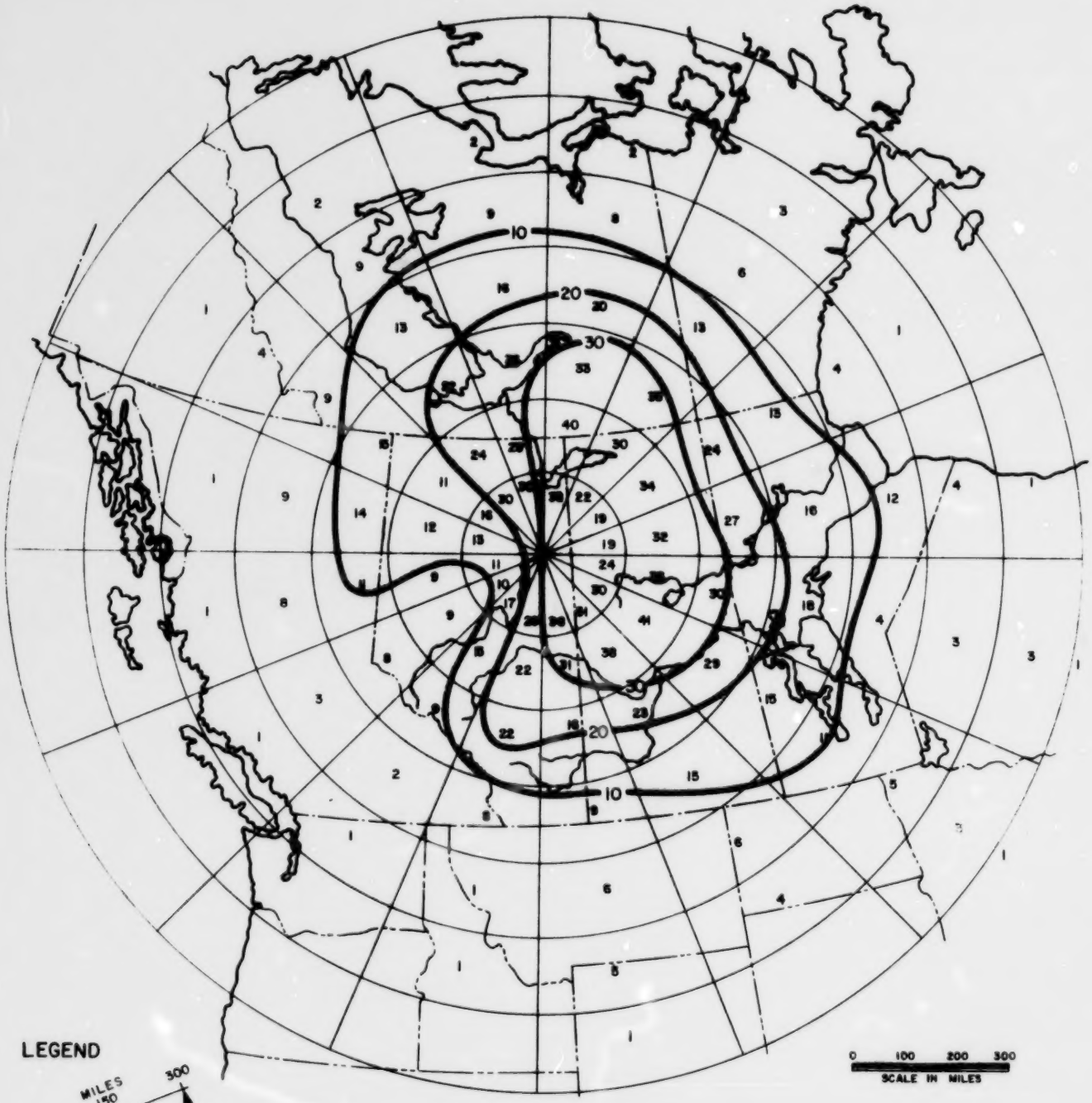
PERIOD – 1968, 73, 74 & 75, DEC., JAN., FEB. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

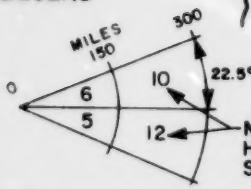
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 72



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

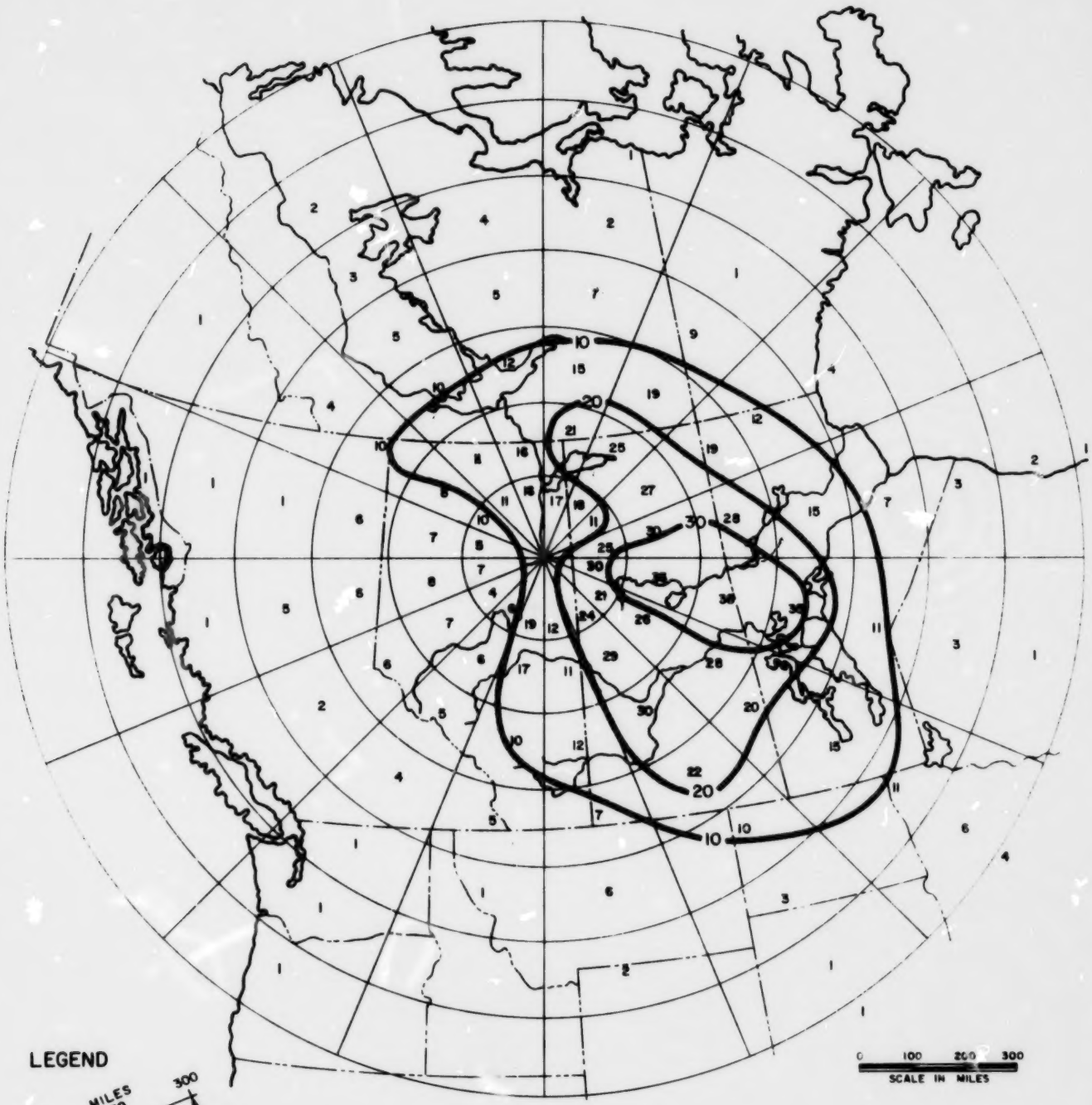
PERIOD – 1968, 73, 74 & 75, MAR., APR., MAY TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

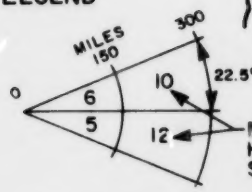
AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 73



LEGEND



NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

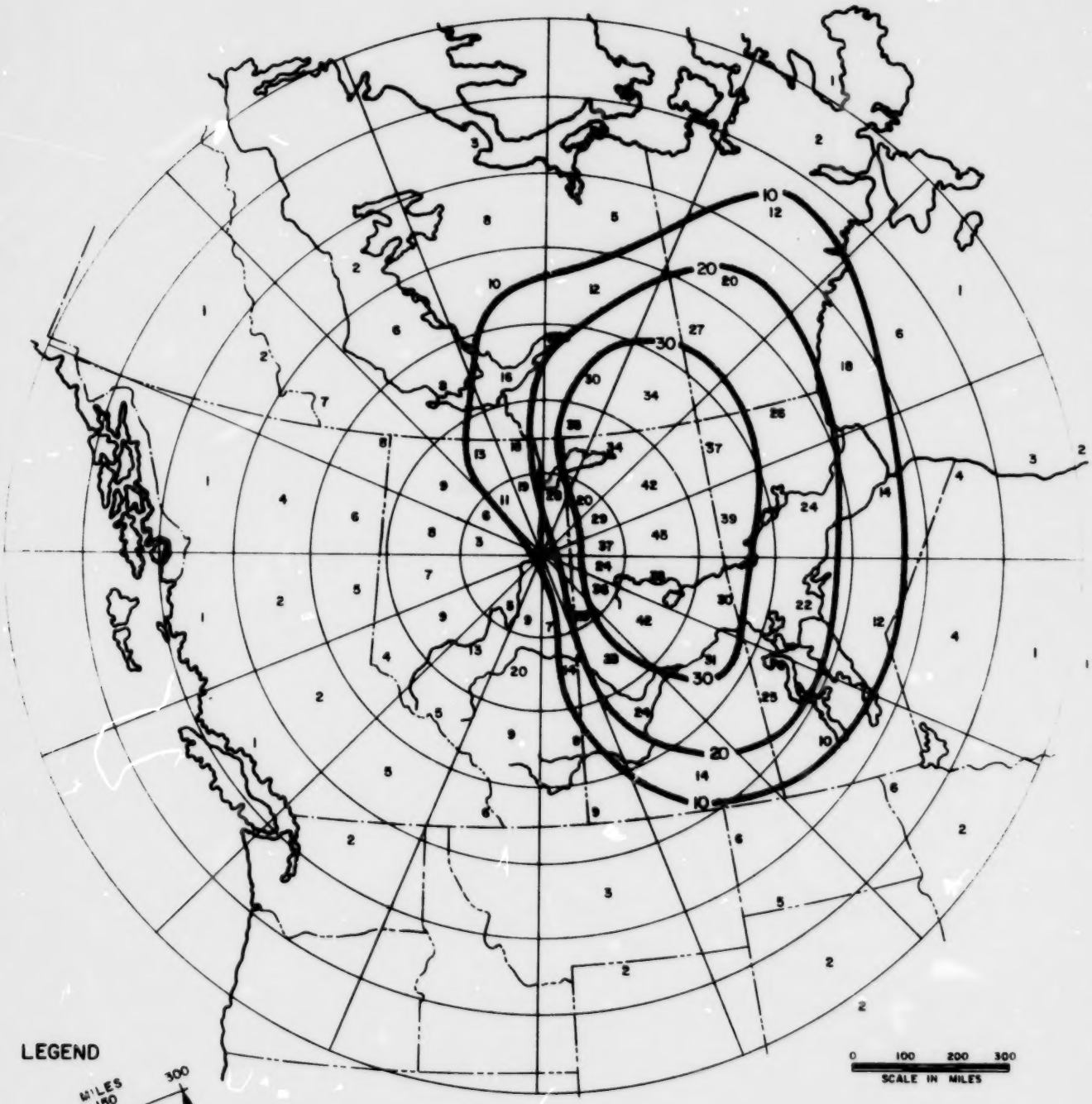
PERIOD – 1968, 73, 74 & 75, JUN., JUL., AUG. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 74



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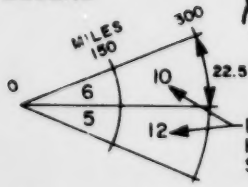

NUMBER OF TIMES AIR PARCELS HAVE MOVED THROUGH A SECTOR IN 4 YEARS

20 ISOLINE OF FREQUENCY

LEVEL – 850 mb

72 HOUR PRECIPITATION – LIGHT

DIRECTION – OUT FROM STUDY AREA

PERIOD – 1968, 73, 74 & 75, SEPT., OCT., NOV. TOTALS

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

AOSERP – 72 HOUR AIR TRAJECTORY ANALYSIS

FREQUENCIES OF AIR PARCEL MOTIONS BY DIRECTION AND DISTANCE FROM STUDY AREA

NOVEMBER 1976 | FIGURE 75

6 - SUMMARY

(a) There are major advantages for handling and speed of viewing to using microfilmed weather maps where analyses are required over several years of record.

(b) Horizontal trajectories can be analyzed with acceptable reproducibility by use of pressure or height contours and plotted wind data at the surface and 850-mb levels.

(c) Comparing air parcel frequency distributions for three consecutive years, 1973-1974-1975, with those for 1968, shows comparable patterns at both the surface and 850-mb levels, with no more than a 45-degree difference in the directions of dominant frequencies. It is concluded that frequency distributions for the entire 4 years closely approach a stable climatological regime.

(d) Consistent patterns of frequency distribution at surface, 925-mb and 850-mb levels show in analyses of 4 year annual totals for precipitation conditions of nil, light, moderate and heavy, although the patterns are less distinct at the surface level in the latter two conditions.

(e) Seasonal patterns of frequency distribution at surface and 850-mb levels are consistent from the west for air parcels moving in to the study area and to the east for air parcels moving out from the study area, except that in spring at the surface the southeasterly directions are somewhat more frequent for air moving in to the study area and the northwesterly directions more frequent for air moving out from the study area.

(f) The analyzed frequencies should satisfy the first objective of the project; viz.,to "contribute to the best design for air and precipitation sampling networks and in the selection of the best locations for sampling soils and lakes to monitor long-term trends in emission deposition".

(g) The large number of trajectory analyses, approximately 8,800, obtained under a full range of synoptic meteorological conditions over the four year period can provide necessary basic input data to meet the second objective of the project; viz., to "serve as the basis for a statistical regional dispersion and deposition model".

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Godske C. L., T. Bergeron, J. Bjerknes, R. C. Bundgaard. *Dynamic Meteorology and Weather Forecasting.* American Meteorological Society and Carnegie Institution of Washington, 1957.

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Wendell, L., Model of Northeastern U.S.A. Sulfur Trajectories. *Symposium on Atmospheric Turbulence and Diffusion, Raleigh, N.C., October 1976.*

Rao, K. S., J. S. Legue and B. A. Egan. Air Trajectory Model for Regional Transport of Atmospheric Sulphates. *Symposium on Atmospheric Turbulence and Diffusion, Raleigh, N.C., October 1976.*

LIST OF PUBLICATIONS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	Preliminary Vegetation Survey of the AOSERP Study Area
5.	HY 3.1	Evaluation of Wastewaters from an Oil Sands Extraction Plant
6.		Housing for the North--Stackwall System Construction Report
7.	AF 3.1.1	Synopsis of the Physical and Biological Limnology and Fishery Programs within the Alberta Oil Sands Area
8.	AF 1.2.1	Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography
9.	ME 3.3	Preliminary Investigation into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10.	HE 2.1	Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area (at print)
11.	AF 2.2.1	Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12.	ME 1.7	Very High Resolution Meteorological Satellite Study of Oil Sands Weather, "A Feasibility Study"
13.	ME 2.3.1	Plume Dispersion Measurements from an Oil Sands Extraction Plant
14.	HE 2.4	Athabasca Oil Sands Historical Research Project (3 volumes) (at print)
15.	ME 3.4	Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area

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For information regarding any of these publications or the Alberta Oil Sands Environmental Research Program, please contact the Program office

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